Transport Canada Transports Canada

TP 3905E

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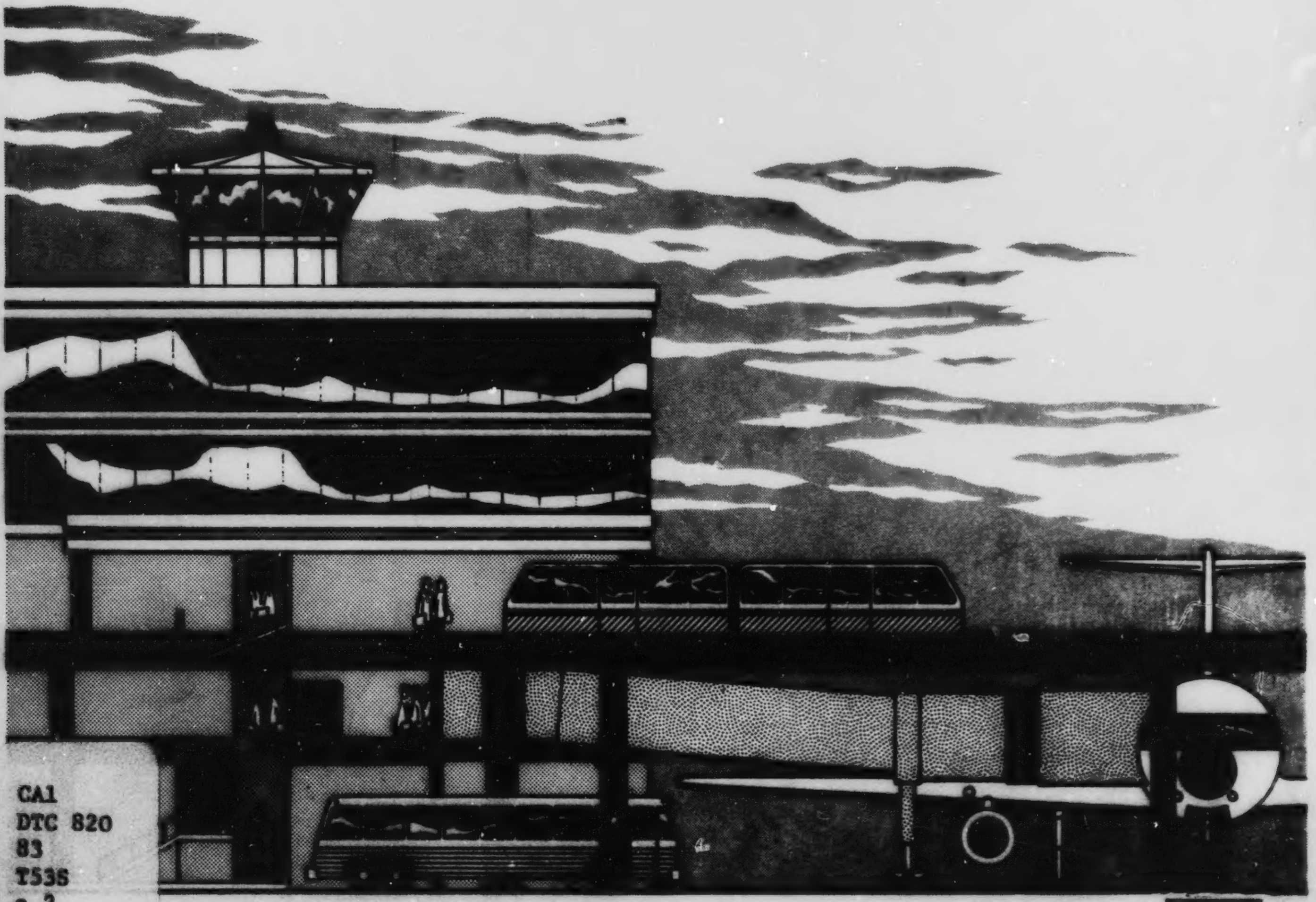
TORONTO INTERNATIONAL AIRPORT
Intra-Airport Transportation Study

Transportati[illegible]evelopment Centre

SUMMARY REPORT

October 1983



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TORONTO INTERNATIONAL AIRPORT
INTRA-AIRPORT TRANSPORTATION STUDY

SUMMARY REPORT

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Transportation Development Centre (TDC)

October 1983

REPORT DOCUMENTATION FORM

1. **Transport Canada Report No.** TP 3905E	2. **TDC Project No.** 4417, 4418, 4419	3. **Recipient's Catalogue No.**
4. **Title and Subtitle** Toronto International Airport Intra-Airport Transportation Study - Summary Report		5. **Report Date** October 1983
		6. **Performing Organization Report No.** TP 3905E
7. **Author(s)** C. Hirou, L.A. McCoomb, T.N. Smith, L. Suen, J. Udell		8. **Transport Canada File No.** D 1455-134-1
9. **Performing Organization Name and Address** Transportation Development Centre 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3		10. **DSS File No.**
		11. **DSS or Transport Canada Contract No.**
12. **Sponsoring Agency Name and Address** Transportation Development Centre 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3		13. **Type of Report and Period Covered** Summary Report
		14. **Sponsoring Agency Code** TDC 4417, 4418, 4419
15. **Supplementary Notes**		16. **TDC Project Officer** L. Suen, L.A. McCoomb

17. **Abstract**

This report summarizes the results of a study by the Transportation Development Centre to evaluate the intra-airport transportation requirements of Toronto International Airport (TIA) to the year 2000 and beyond, and to develop technical alternatives to meet these requirements. The nature of the intra-airport problem at TIA is briefly reviewed, namely inter-terminal transfers, traffic congestion and access to parking, accommodation and public transit. The report outlines the systems analysis approach used to address these problems and describes the three alternatives selected for detailed evaluation by TIA, namely an intermediate-capacity elevated guideway system, a tunnelled light guideway system and a conventional shuttle bus system. The final section of the report describes the procedure for determining the technical alternative best suited to each of the TIA land use development options. One interesting conclusion of the study is that the expansion to a three-terminal airport configuration will not necessitate the high-technology guideway circulation system; whereas, if a new remote parking facility is added to the current two-terminal airport configuration, the high-technology, intermediate-capacity guideway system will be required.

18. **Key Words** Toronto, Airport, Terminal, Planning, Intra-Airport, Transport		19. **Distribution Statement** Copies available from Transportation Development Centre.	
20. **Security Classification (of this report)** Unclassified	21. **Security Classification (of this page)** Unclassified	22. **No. of Pages** 58	23. **Price** Nil

TDC/CDT 79-005

FORMULE DE DOCUMENTATION POUR RAPPORT

1. Nº du rapport Transports Canada TP 3905 E	2. Nº de l'étude — CDT 4417, 4418, 4419	3. Nº de catalogue du destinataire

4. Titre et sous-titre

Toronto International Airport Intra-Airport Transportation Study - Summary Report

5. Date du rapport

Octobre 1983

6. Nº du rapport de l'organisme exécutant

TP 3905 E

7. Auteur(s)

C. Hirou, L.A. McCoomb, T.N. Smith, L. Suen, J. Udell

8. Nº de dossier Transports Canada

D 1455-134-1

9. Nom et adresse de l'organisme exécutant

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10. Nº de dossier – ASC

11. Nº de contrat — ASC ou Transports Canada

12. Nom et adresse de l'organisme parrain

Centre de développement des transports (CDT)
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Suite 2421
Montréal, Québec H3A 2R3

13. Genre de rapport et période visée

Rapport sommaire

14. Code de l'organisme parrain

CDT 4417, 4418, 4419

15. Remarques additionnelles

16. Agent de projet — CDT

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17. Résumé

Ce rapport récapitule les travaux d'une étude conduite par le Centre de développement des transports en vue de définir les besoins de l'Aéroport international de Toronto (AIT) pour un réseau de transports aéroportuaires en l'an 2,000 et plus loin, et de trouver les solutions techniques correspondantes. Il passe en revue la nature du problème soulevé par l'Aéroport et, notamment, les déplacements entre aérogares, la densité du trafic et l'accessibilité des parkings, des hôtels et des services de transport collectif. Il décrit succinctement l'approche systémique utilisée pour s'attaquer au problème et esquisse les trois filières retenues qui doivent faire l'objet d'étude plus poussées: un système à capacité intermédiaire à voie surélevée, un système de transport léger en tunnel et une navette routière de type classique. La dernière partie du rapport est consacrée à la description de la méthode utilisée pour déterminer l'option la plus avantageuse pour chacun des scénarios envisagés par l'Aéroport en matière d'occupation des sols. Une constatation intéressante de l'étude a été qu'on pourrait ne pas faire appel au système à voie surélevée (option à technologie de pointe) si on dotait l'aéroport d'une troisième aérogare, tandis que si on adjoignait aux deux aérogares existantes un terrain de stationnement éloigné, un tel système deviendrait indispensable.

18. Mots-clés

Aéroport international de Toronto. Aérogare. Planification. Transports aéroportuaires.

19. Diffusion

Le CDT dispose d'un certain nombre d'exemplaires.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
Non classifié	Non classifiée	58	Aucun

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the advice and assistance provided by the Project Team for this work. The contribution of consultants on various aspects of the study is also recognized.

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SUMMARY

In 1980 the Transportation Development Centre of Transport Canada was tasked by the planning staff of Toronto International Airport (TIA) to carry out a study to examine the intra-airport transportation requirements at Toronto International Airport to the year 2000 and to develop and assess alternative plans to meet these requirements. The need for this study was precipitated by the planning of a third terminal at TIA. Increased inter-airline transfers created by a three-terminal airport necessitated the development of an analytical tool and methodology to assess the transportation system options for connecting the key airport activity centres.

In addition to serving inter-terminal transfers, it was also foreseen that an improved intra-airport transportation system would: a) reduce the problems caused by severe traffic congestion on the airport road system, particularly on the approach to Terminal #1; b) help to ease the parking capacity shortfalls at Terminal #1 and those that will be caused by the construction of Terminal #3; c) improve the productivity of the regional bus systems now serving TIA by permitting a centralization of their operations; d) promote a mode shift to transit for airport employees and users by providing a high-quality connection between the airport activity centres and the proposed rail transit link; and, e) serve an airport hotel complex, should such a development take place.

To ensure a proper balance was struck, this study was carried out in concert with other key airport planning activities, namely: the airport master plan, the airside capacity plan, the Terminal #3 plan (beginning with the optimization study of Terminals #1 and #2) and the Metropolitan Toronto rapid transit expansion plan.

Because of the wide range of possible alternatives (i.e. technologies, system layouts, modes of operation, etc.) for an improved intra-airport transportation system, the study was conducted in two phases. The first phase of the study examined transportation system alternatives using seven critical criteria: (a) life-cycle cost, (b) convenience to users, (c) accessibility to airport activity centres, (d) reliability, (e) ease of implementation, (f) flexibility to meet unforeseen changes in demand and (g) environmental impact. This first-phase evaluation resulted in a shortlisting of the alternatives to three candidate systems,

each of which is optimal over a particular range of applications to the airport. These candidate systems were:

- Shuttle Bus System - for low-demand situations (0-1500 passengers per hour per direction (pphpd), using conventional (35-50 passenger) diesel transit buses operating on priority or dedicated rights-of-way.
- Tunnelled Guideway Systems - for medium-demand situations (500-2000 pphpd) using small (36-60 passenger) automated, electrically powered trains of the WEDway or powered SailRail type (currently being developed by UTDC), operating in a tunnel.
- Elevated Guideway Systems - for high-demand situations (1500-5000 pphpd) using large (60-120 passenger) electrically powered trains of the UTDC ICTS or Westinghouse people movers, operating on an elevated, concrete guideway.

Demand estimates were prepared from nominal schedules for the years 1985, 1991 and 2000, and from these, peak-hour and annual ridership estimates were formulated for each potential land use development and/or policy option. It was the goal of phase two of the study to determine which of the candidate transportation systems identified in phase one would best serve each of the operating policy and land use development options and, in so doing, to trace out the intra-airport transportation implications (i.e. required capacity, level of service, cost, etc.) of each of these options.

A greatly expanded list of evaluation criteria was considered in the second phase of the analysis including: comfort, safety and security, luggage and cargo handling capability, equity and energy consumption. Functional designs were produced for each of the candidate transportation systems, defining routes, station locations and layouts, operating schedules, etc. The design was carried to a sufficient degree of detail to permit the quantification of all of the evaluation criteria.

A computer model was developed to assist in the detailed evaluation. By specifying the anticipated annual growth rate for air traffic, the desired land use development plan, the transportation system, the discount and inflation rates, the expected useful life of equipment, maximum capacities, minimum policy headways, and hours of peak and off-peak operation, the study team determined the life-cycle costs and level-of-service parameters for the three systems studied.

It was the intent of this study to provide an analytic tool to help decision makers evaluate the airport development options. Because there are so many possible development options, it was not practical to evaluate them all. Instead, three development options of particular interest to the airport planning staff were analyzed as case studies.

Case Study #1

Assumed very low annual passenger growth rates (1 per cent) and therefore does not provide for a third passenger terminal in the immediate or medium term.

It is assumed that a central parking structure will be constructed north of the Administration Building to accommodate existing and future T-1 shortfalls. No provision is made for the accommodation of employees or a centralized ground (bus) transportation terminal.

Case Study #2

Assumed higher average annual growth rates (3.1 per cent) and that a third terminal (with associated parking structure) will be constructed. As with Case Study #1, no provision is made for the accommodation of employees or for a centralized ground transportation terminal.

Case Study #3

Assumes the same annual traffic growth rates and passenger terminal configuration as in Case Study #2. In addition it is assumed that a central ground transportation terminal contiguous with a parking/hotel complex is constructed north of the Administration Building. Provision is also made for the accommodation of airport employees in the system.

The following preliminary conclusions were drawn from the study:

a) The tool presented in this study provides decision makers with a clear understanding of the ground transportation implications of pursuing any one of a wide range of development options for TIA. It should be stressed, however, that this tool assists the decision maker in selecting an appropriate transportation system for a specific development option. It should also be noted that information on non-user impacts (e.g. traffic non-user impacts (e.g. traffic congestion) of development options is not currently available, thus should be accounted for separately in the decision process.

b) If no third terminal is to be constructed in the short to middle run (case study #1), and every effort is made to optimize the use of the existing facilities at TIA, then the capital investment in a high-capacity, high-performance elevated guideway system is required and justifiable. The high-performance elevated guideway system would ensure that the available groundside capacity at Terminal #2 can be mobilized in support of Terminal #1. It can also be used to ensure that adequate capacity and level of service can be provided on the critical system link between Terminal #1 and the central parking structure required to accommodate the parking shortfall at Terminal #1.

c) If a large capital investment is made in a third terminal (case study #2), which is designed as a self-contained facility to relieve the congestion at Terminal #1, then there is little or no justification for large investment in an intra-airport transportation system as the need for movement about the airport is minimal.

d) If decisions are taken to adopt the airline preferred scenario for carrier allocation to the terminals, that the ground transportation system is to carry employees and that a central (bus) ground transportation facility is to be constructed, a high-performance transportation system will be required. In other words, with the three-terminal case, the investment in a high-performance intra-airport transportation (guideway) system can be justified if certain policy decisions regarding employees, transit access, etc. are adopted (case study #3).

e) The conclusions presented in this study must not be considered in isolation but rather must be assessed in conjunction with traffic engineering analysis, airside capacity analysis and terminal needs analysis to evaluate the full range of options open to the airport. A balanced approach must be sought under which all opportunities and constraints are considered and an optimal staged approach to the further development of TIA is pursued.

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1. INTRODUCTION

In September 1979, the Southern Ontario Multimodal Passenger Study* stated that a decision to develop additional airport facilities at the Toronto International Airport (TIA), Malton, would be required immediately, owing to projected traffic growth and the abandonment of plans for an airport in Pickering, Ontario.

TIA undertook two major activities in 1980, namely the development of an airport master plan and the development of conceptual plans for additional airport facilities, including the option of a third terminal.

TIA planners realized at the outset of this exercise that the efficient operation of an airport system demands a balanced capacity of the runway, terminal and ground transportation systems. The consideration of a third terminal at TIA therefore called for not only an examination of the requirements for the terminal itself, but also an evaluation of the impact on airside capacity and on the ground transportation system. The TIA planning team undertook the examination of the airside capacity and tasked the Transportation Development Centre (TDC) of Transport Canada to study the impact on the intra-airport ground transportation system. This summary report outlines the findings of TDC's analysis of the intra-airport transportation alternatives for TIA.

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* Transport Canada, Ministry of Transportation & Communications, Ontario, Southern Ontario Multimodal Passenger Study, September 1979.

2. THE PROBLEM

The problem faced by TIA is one faced by many mature airports: only limited expansion in the vicinity of the existing terminal complex is possible. Expansion of terminal and parking facilities must therefore occur away from the heart of the existing activity centre. In the case of TIA, these future developments will likely be well beyond acceptable walking distances, thus requiring the provision of some form of intra-airport circulation system (i.e. shuttle buses, guideway systems, moving sidewalks, etc.) to smoothly and efficiently move people between activity centres.

TIA's intra-airport ground transportation problems, created by increasing airport traffic, can be broken down into six basic elements, as follows:

2.1 Problem #1 - Transferring Passengers

TIA currently has two passenger terminals connected by a shuttle bus service and an underground pedestrian tunnel equipped with a moving sidewalk. It is forecast that a third terminal will be required to handle future growth in air traffic. The site earmarked for this new terminal (T3) is over one thousand metres west of the existing terminals, well beyond reasonable walking distance and cut off from the existing terminals by a cargo and aircraft maintenance area. A serious intra-airport transportation problem is foreseen to occur when the airlines serving TIA must be assigned to three terminals rather than two and transferring passengers must make connections at different terminals. Of course, much can be done to minimize the need for inter-terminal transfers by a judicious allocation of the airlines among the terminals; unfortunately inter-terminal transfer is not the only factor in airport design. When other important factors of air traffic at terminals, such as demand peaking, are considered, allocating the airlines on the basis of minimizing inter-terminal transfer could be very wasteful, especially in terms of optimizing the use of the large capital resource represented by the terminal itself.

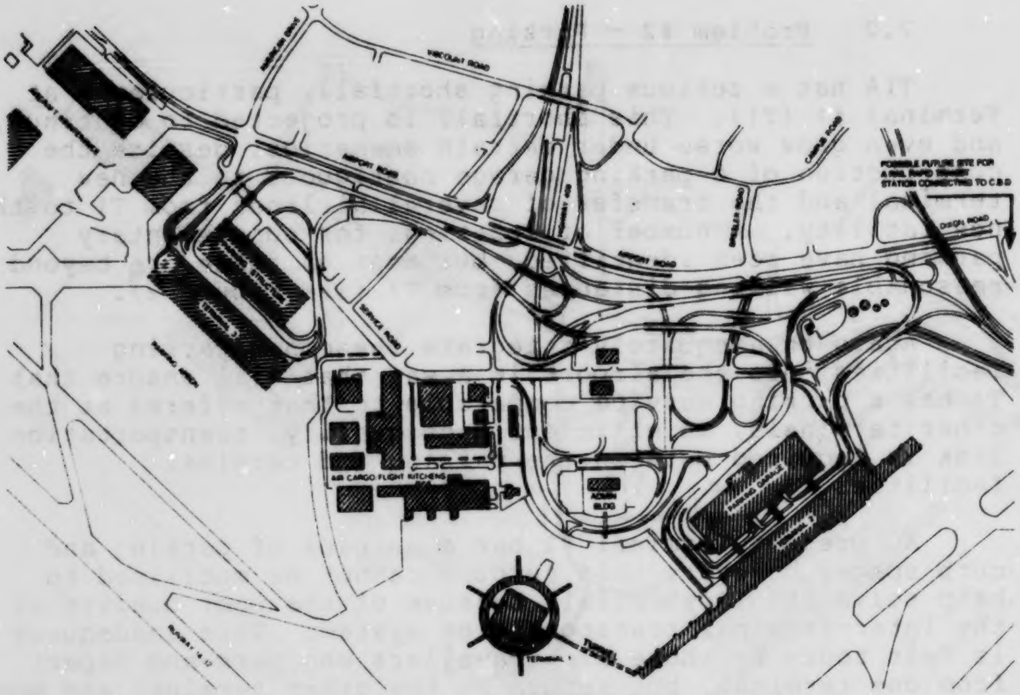

VISCOUNT ROAD
AIRPORT ROAD
AIRPORT ROAD
POSSIBLE FUTURE SITE FOR A RAIL RAPID TRANSIT STATION CONNECTING TO C.B.D
DIXON ROAD
SERVICE ROAD
AIR CARGO FLIGHT KITCHENS
ADMIN BLDG
PARKING GARAGE
TERMINAL 2
TERMINAL 1

Figure 1 Toronto International Airport

The possibility also exists that more efficient use could be made of airport gate positions by pooling them and, in effect, operating all terminals as one. In such an arrangement, passengers might be processed in one terminal, but transferred to another for departure. Similarly, rather than having both aircraft and passengers wait while gates stand empty, arriving passengers would deplane at an available gate at any one terminal and transfer to their airline home terminal. Although the prospect of such an arrangement is not a particularly happy one for most airlines, it certainly makes economic sense when one considers that this type of operation would only be necessary during the summer peak period. It is difficult to rationalize the cost of providing additional gates to handle peak periods when it is known that gates will stand empty at adjacent terminals. To make this pooled gate concept workable, a high-quality (i.e. rapid and frequent) inter-terminal transportation service is required, ideally one that would transfer people between terminals as easily as elevators transfer them between floors.

2.2 Problem #2 - Parking

TIA has a serious parking shortfall, particularly at Terminal #1 (T1). This shortfall is projected to continue, and even grow worse under certain scenarios, despite the construction of a parking garage contiguous to the new terminal and the transfer of several airlines from T1 to the new facility. A number of locations for supplementary parking have been identified, but most of these are beyond reasonable walking distances from T1 (see Figure 2).

Again to adequately integrate these new parking facilities into the airport in a way that will ensure that T1 has a parking service comparable to that offered at the other terminals, an efficient high-quality, transportation link is required between the parking and terminal facilities.

At present Terminal #2 has a surplus of parking and curb space; however, this surplus cannot be mobilized to help solve the T1 shortfall because of the poor quality of the inter-terminal transportation system. This inadequacy is felt today by those air travellers who park and depart from one terminal, but return by the other terminal and must make their way back to their cars. This group of travellers would greatly benefit from a high-quality transportation link between the terminals.

2.3 Problem #3 - Traffic Congestion

Designed in the early sixties, Terminal #1 is a round building encircled by the aircraft apron and gates. Auto and bus traffic access the terminal's curbs and central parking garage through a road tunnel under the apron. The geometric design of this tunnel is much too constrained to cope with current traffic demand. During peak periods, traffic queues from this bottleneck cause long delays for travellers arriving by automobile or bus. One solution to this traffic problem is to channel traffic to a remote curb or parking facility before it reaches the tunnel bottleneck and then transport the passengers and others from this remote location to Terminal #1. Only a high-quality transportation system could be expected to attract traffic away from direct access to T1's curbside and parking complex, hence helping to ease traffic congestion (see Figure 2).

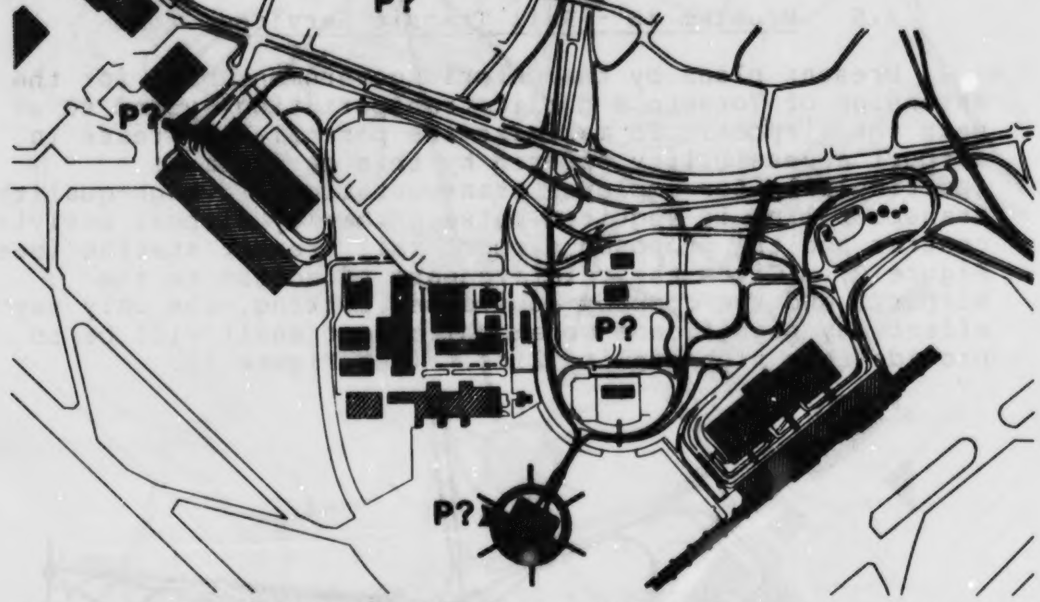


Figure 2 Potential Parking Sites and Access Road Congestion

2.4 Problem #4 - Bus Service

TIA serves as a hub airport for much of southern Ontario. As such, it attracts airport bus service from not only downtown Toronto, but also from a wide radius of surrounding communities. These buses are currently forced to serve each terminal separately, first dropping off passengers at departure levels, then circling to load passengers at the arrival levels. This multi-stop operation, coupled with the airport's circuitous road system (see Figure 2), imposes additional delays on passengers and seriously impairs the productivity of the buses, which spend a good deal of time at the airport rather than transporting people to and from it. Moreover, the buses themselves constitute a major source of congestion at T1 where, again, limited road geometries restrict the manoeuvrability of these large vehicles. This problem will be aggravated if the buses are forced to serve three terminals. One method of improving bus productivity and service is to provide a central bus station at the airport. To make this practicable, however, a high-quality ground transportation link must be provided between the air terminals and the central bus station. Spin-off benefits of such a development would be the freeing of valuable curb space for other airport users and the simplifying of matters for bus users, who would be transported to their own terminal, rather than having to find their way in the hustle and confusion at curbside (see Figure 3).

2.5 Problem #5 - Rail Transit Service

Present plans by the Ontario government call for the extension of Toronto's public transportation system to or near the airport. To maximize the potential increase in airport accessibility offered by this development (particularly for employee transportation), a high-quality transport link is required between the key airport activity centres and the proposed airport rail transit station (see Figure 2). Given the relative ease of access to the airport, and the company-subsidized parking, the only way to effect any significant modal shift to transit will be to provide this high-quality link. (see Figure 3).

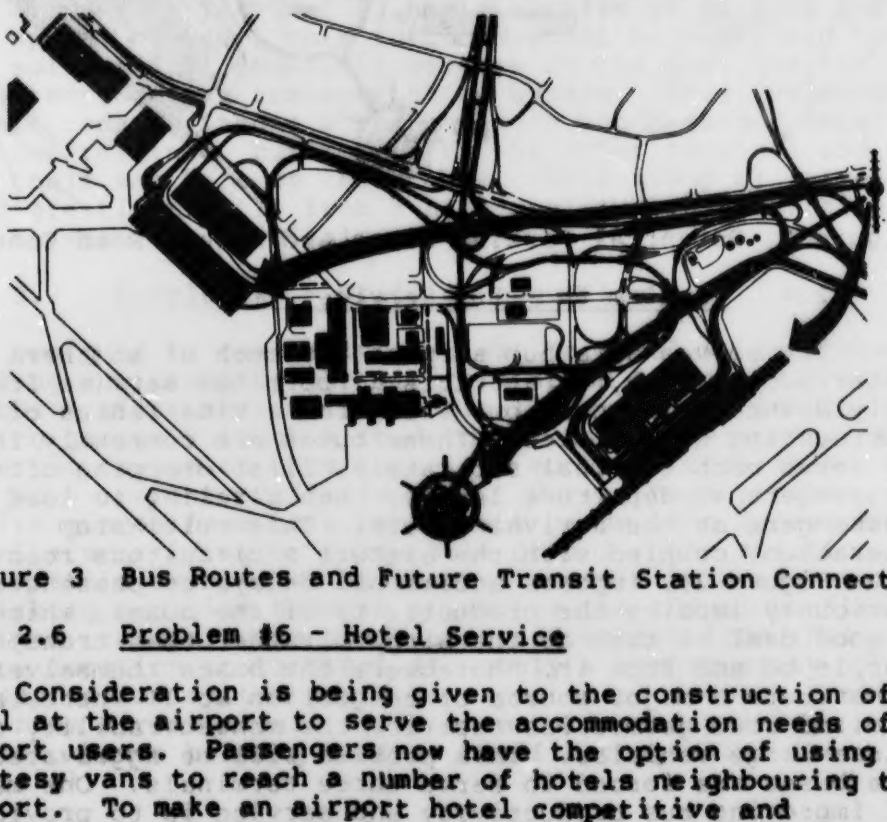


Figure 3 Bus Routes and Future Transit Station Connection

2.6 Problem #6 - Hotel Service

Consideration is being given to the construction of a hotel at the airport to serve the accommodation needs of airport users. Passengers now have the option of using courtesy vans to reach a number of hotels neighbouring the airport. To make an airport hotel competitive and profitable, a transportation system will be required to link the hotel to the passenger terminals and other airport activity centres (see Figure 4).

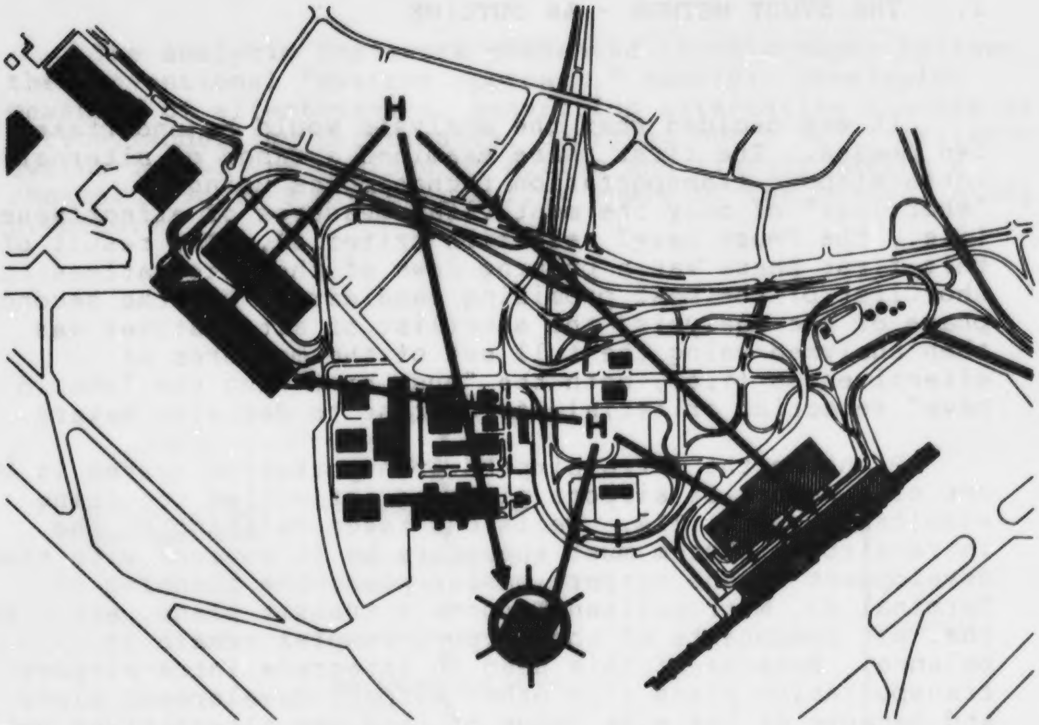


Figure 4 Service to Airport Hotels

In summary, it can be concluded that the need for an intra-airport transportation system to link the major centres of activity on the airport is one that will become more pressing as the airport expands. The question this study is directed to answer is: what type of circulation system will best meet this need?

In recognition of the complexity of the intra-airport transportation problem at TIA and the wide range of alternative solutions to this problem, it was decided that a systems study was required, with the following objective:

> To examine the intra-airport transportation requirements at Toronto International Airport to the year 2000 and to develop and evaluate alternative plans to meet these requirements.

3. THE STUDY METHOD - AN OUTLINE

It was decided that the analysis would be undertaken in two phases. The first phase examined a range of alternative intra-airport transportation technologies using a "shortlist" of only the most vital measures of effectiveness (i.e., the "must have" selection criteria). The result of this first phase was a pruning down of the alternatives to a shortlist of the most promising candidates. In the second phase of the analysis, the shortlist of alternatives was then analyzed using the full set of the measures of effectiveness (i.e., both the "must have" and the "should have" selection criteria) of interest to decision makers.

Planning the intra-airport transportation system is but one of a number of airport planning activities occurring simultaneously at TIA. Decisions taken relating to the intra-airport system must therefore be in concert with the development of the airport master plan, the planning of Terminal #3, Metropolitan Toronto's transit plans, etc., so that all components of the airport complex remain in balance. Because of this need to integrate intra-airport transportation plans with other airport development plans and because of the wide range of land use alternatives being considered (each of which would generate quite different demands on the intra-airport circulation system), this systems analysis technique was specially structured to provide decision makers with a highly flexible analytic tool.

The aim was not to undertake a conventional systems study leading to a single recommendation, but rather to establish a decision-aiding framework that would help decision makers gain an in-depth understanding of the implications for intra-airport circulation of the various land use and policy questions being considered. This analytic tool would clarify in the minds of decision makers such questions as the demands for intra-airport transportation generated by each operating policy or land use plan, the feasible technologies to serve each demand level, and the trade-offs between cost and level of service that must be considered in making a final choice of system. Carrying out the systems analysis in this fashion allows its full integration into the larger development process for the airport. It also increases the chances of a globally optimal and consistent set of decisions on airport expansion.

The analytic framework presented in this paper follows the conventional "systems approach," namely: developing measures of effectiveness, generating alternative courses of action, modelling performance, carrying out a multi-criteria evaluation of the courses of action and finally making a choice. Figure 5 presents a flow chart of the overall study procedure.

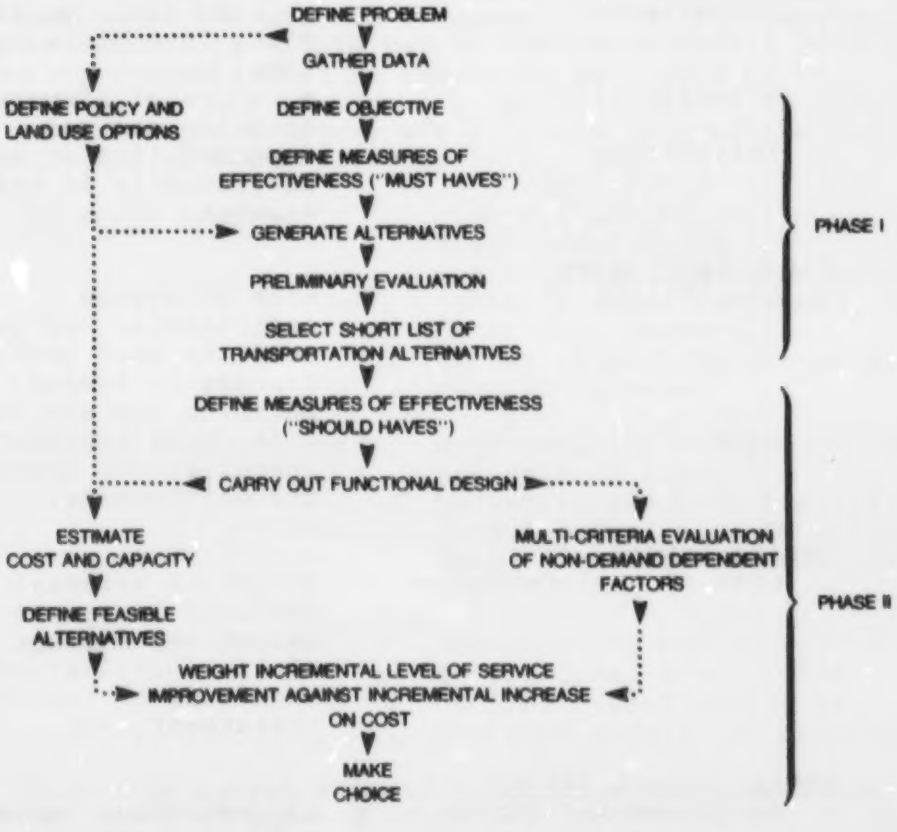

DEFINE PROBLEM
GATHER DATA
DEFINE POLICY AND LAND USE OPTIONS
DEFINE OBJECTIVE
DEFINE MEASURES OF EFFECTIVENESS ("MUST HAVES")
GENERATE ALTERNATIVES
PRELIMINARY EVALUATION
SELECT SHORT LIST OF TRANSPORTATION ALTERNATIVES
PHASE I
DEFINE MEASURES OF EFFECTIVENESS ("SHOULD HAVES")
CARRY OUT FUNCTIONAL DESIGN
ESTIMATE COST AND CAPACITY
MULTI-CRITERIA EVALUATION OF NON-DEMAND DEPENDENT FACTORS
DEFINE FEASIBLE ALTERNATIVES
PHASE II
WEIGHT INCREMENTAL LEVEL OF SERVICE IMPROVEMENT AGAINST INCREMENTAL INCREASE ON COST
MAKE CHOICE

Figure 5 Flow Diagram of Study Methodology

4. MEASURES OF EFFECTIVENESS

Subsequent to a full definition of the problem and coincident with related analyses, i.e. demand forecast, parking options, etc., the first iteration of the systems analysis identified seven essential criteria against which the widest possible range of transportation systems were to be tested. These "must have" criteria fell under four general headings and include:

Transportation issues
. convenience - walking time, waiting time, in-vehicle travel time, etc.
. accessibility - coverage of airport activity centres.
. reliability - dependability of service, particularly in bad weather.

Financial issues
. flexibility - ease of system modification, at low cost, to meet unforeseen changes in demand patterns (up and down).
. cost - life-cycle costs of installation, operation and maintenance.

Social issues
. ease of implementation - number of external actors involved in system selection, disruptiveness of the installation, magnitude of the initial investment, etc.

Environmental issues
. environmental impact - air emissions, noise pollution, visual intrusion, etc.

For each transportation alternative, the criteria were defined in terms of one or more quantifiable measures of performance and, where practical, performance requirement thresholds were defined for purposes of comparison.

5. THE TRANSPORTATION SYSTEM ALTERNATIVES

The intra-airport circulation system alternatives to be examined as part of the first phase of this project were generated by combining elements from four key features of a transportation system, namely the technology, the mode of operation, the alignment and the type of right-of-way.

5.1 Technology

A wide spectrum of transit equipment is available for application to the airport circulation problem, ranging from complex subways to simple pedestrian concourses. An initial screening was conducted to remove those judged to be impractical for application at TIA (for reasons of capacity, cost, weather performance, etc.). This reduced the list of technologies to the following:

Guideway Systems	. UTDC (linear induction motor, steel wheel on rail) . Westinghouse (traction motor, rubber tire on concrete) . Cabin Taxi (monorail) . WEDway (linear induction motor, passive vehicle)
Shuttle Bus Systems	. High-capacity buses, e.g. GM articulated bus . Conventional urban transit diesel buses, e.g. GM New Look . Small diesel buses, e.g. Orion bus
Pedestrian Systems	. Accelerating moving way, e.g. S-Type Speed-a-way, TRAX . Constant speed moving way . Enclosed pedestrian concourse

This list covers a broad range of systems measured in terms of level of service, capacity, technological sophistication, precedence and cost. After this list of alternatives was determined, site visits were conducted to a number of airports to discuss experiences and ideas. Visits were carried out to airports with problems similar to those at Toronto International, such as the John F. Kennedy Airport (New York) with its 12-terminal system and Kansas City airport, which has three terminals and an annual traffic volume close to that at TIA, and airports that have experimented with high-technology circulation systems (such as Dallas-Fort Worth with AIRTRANS, Houston with WEDway, Atlanta with Westinghouse).

5.2 Mode of Operation

Two modes of system operation were considered, namely: (a) shuttle service, where the vehicles reverse direction on a single or double track line, and (b) loop service, where vehicles move continually in one direction around an open loop serving each station only once on each cycle.

5.3 Alignment

A number of alignment configurations were considered, including: (a) connecting stations on a single line,
(b) connnecting stations on a large open loop,
(c) connecting stations to a central hub with radial lines and (d) combinations of these concepts.

5.4 Right-Of-Way

Three basic types of right-of-way were considered:

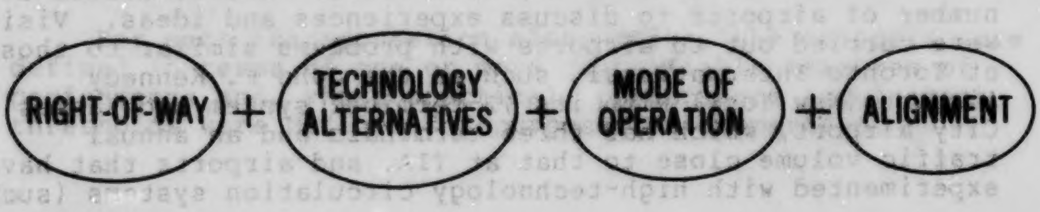
(a) Elevated - with the system mounted on a concrete, elevated guideway

(b) Surface - with the system operating at ground level:
  (i) in mixed traffic
  (ii) in a lane where it has priority for movement over other traffic
  (iii) in an exclusive lane, dedicated to its use

(c) Tunnelled - with the system operating underground in a bored or cut-and-cover tunnel.

5.5 Alternatives

The technical alternatives to be evaluated were generated by combining elements from each of the four features above.



Obviously certain combinations are impractical and were eliminated, e.g., a guideway system (with active high-voltage third rail) running on a surface right-of-way in mixed traffic. In all, 30 feasible technical combinations were generated.

A broader range of alternatives might have been considered in planning and managing intra-airport transportation, particularly policy alternatives relating to the use of pricing to control demands. Under the terms of reference for this study, however, the scope of work was limited to examining technical alternatives only.

6. PHASE I: PRELIMINARY EVALUATION

The preliminary evaluation based on the seven previously described critical criteria was carried out using a subjective ranking scheme to measure the performance of each of the technical alternatives. The rating scale ranged from 0 to 5, with "0" indicating unacceptably poor performance and "5" indicating outstanding performance.

6.1 Impact Groups

The importance of each criterion to the choice of a system depends very much on the perspective of the group affected. Six impact groups were identified as having a unique interest in the airport problem; these included:

- Transport Canada (airport management)
- Airport users (passengers, wellwishers, greeters, etc.)
- Airport employees
- Airline operators
- Ground transportation operators (taxis, limousines, etc.)
- Public (represented by other levels of government)

Separate weightings were developed for the importance of each criterion to each impact group. For example, it is reasonable to assume that airport users will place a higher premium on convenience than will the non-user public, whereas the non-user public neighbouring the airport will likely be more concerned about the environmental impact of any additions to the airport than would airport users. Initially the impact group weightings for each group were estimated by the study team. In the second phase of the analysis, these weightings were actually measured using focus group interviews. The composite weighted performance of the technical alternatives, as perceived by each impact group, were computed from these weightings.

6.2 Envelope of Optimal Alternatives

Based on the results of the preliminary evaluation, a plot (Figure 6) was prepared comparing the life-cycle cost of each alternative, in current dollars, against its effectiveness, measured as a subjective composite index of system performance, particularly system capacity and level of service. Those alternatives along the top edge of this "cost/effectiveness curve" represent the envelope of technically optimal alternatives for the full spectrum of capacities and levels of service. In simple terms, this "expansion path" identifies the best value for the money, in terms of the choice of feasible technical alternatives, for each level of service.

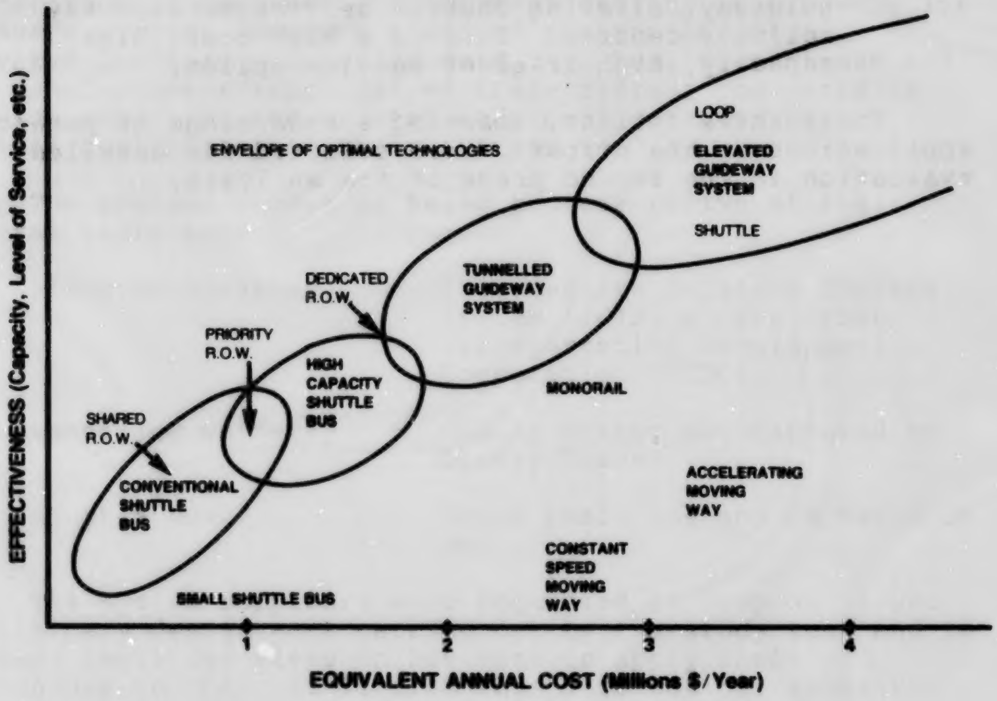


Figure 6 Envelope of Optimal Intra-Airport Circulation Systems

6.3 Phase I Recommendations

The result of the preliminary evaluation was a narrowing down of the technical alternatives to a shortlist of three, as follows:

- shuttle buses operating on a surface shared right-of-way, in a one-directional, open-loop service connecting key activity centres. Priority treatment and progressively larger vehicles can be added as traffic increases over the years to justify such improvements. This is a low cost, low capacity, low level of service option.

- tunnelled guideway systems using small (10-20 passenger) "people mover" vehicles, offering two-directional loop service, underground. This is a high cost, medium capacity, high level of service option.

- elevated guideway systems using large (50-80 passenger) "people mover" vehicles on an elevated guideway, offering shuttle service between key activity centres. This is a high cost, high capacity, high level of service option.

These three options, spanning a wide range of potential applications at the airport, were selected for detailed evaluation in the second phase of the analysis.

7. PHASE II: DETAILED EVALUATION

The detailed evaluation of the three candidate transportation systems demanded that a great deal more be learned about their potential application and performance than was required for the preliminary evaluation. To permit preparation of meaningful functional designs, representative hardware systems for each class of alternative, i.e., elevated guideway, tunnelled guideway, bus, were chosen and the manufacturers/suppliers of these systems requested to provide expert advice on what they considered to be the optimal application of their systems to TIA.

The systems chosen as being representative of their general class were:

elevated guideway - Intermediate Capacity Transit System (ICTS) of the Urban Transportation Development Corporation (UTDC)

tunnelled guideway - WEDway System manufactured by Disney/Turner

shuttle bus - Orion small bus and GM New Look bus

The system suppliers were requested to respond to the preliminary design work carried out by the study team and to present their own views on how best to apply their technology to TIA. It is from this information, augmented with general published reference materials on these systems and consultant studies, that the facts and figures used in the comparative evaluation were drawn.

It is emphasized that the systems of the three specific manufacturers included in the comparative analysis were chosen as being representative of a general class of alternatives. Naming a specific supplier was necessary to obtain expert input to the design process and the technological details necessary for a meaningful comparison of the options. The choice of these systems in no way represents endorsement of the manufacturers, nor do the results of this evaluation signify a choice of a particular manufacturer. What the evaluation does provide is a clear indication of the general requirements of the optimal system. From these general requirements a performance specification can be prepared and bids solicited from all manufacturers capable of meeting the general terms of this specification.

A description of each of these systems as applied to TIA follows.

7.1 UTDC's Intermediate Capacity Transit System (ICTS)

The Urban Transportation Development Corporation's ICTS in an airport application would consist of 60-passenger vehicles operating in one- or two-car trains. The system employs a steerable, steel-wheel-on-rail suspension, which reduces noise and energy consumption. All-weather performance is ensured by the use of linear induction motors (LIMs) for traction and service braking. This type of motor develops thrust through the direct action of a magnetic field between the vehicle mounted primary motor winding and track mounted secondary. This eliminates the traction problems associated with conventional rotary power, which develops thrust by torquing the wheels. Vehicle performance and flexibility of a moving block train control system permits safe, reliable operation at short headways. A possible ICTS alignment at TIA is shown in Figure 7. A view of the elevated concrete guideway through Terminal #1 is shown in Figure 8. Figure 9 shows a cross section through the ICTS maintenance area, shown here as part of a proposed parking garage behind the administration building.

This system is representative of other "people movers" of this general size, such as the Westinghouse Transit Expressway system used at airports in Atlanta, Tampa, Seattle, Miami, Orlando and London (Gatwick) and the AIRTRANS system used at the Dallas-Fort Worth Airport, with the notable exception that these other systems use rubber tired suspension and conventional electric rotary traction motors. Both Westinghouse and AIRTRANS have done extensive research on winter operations.

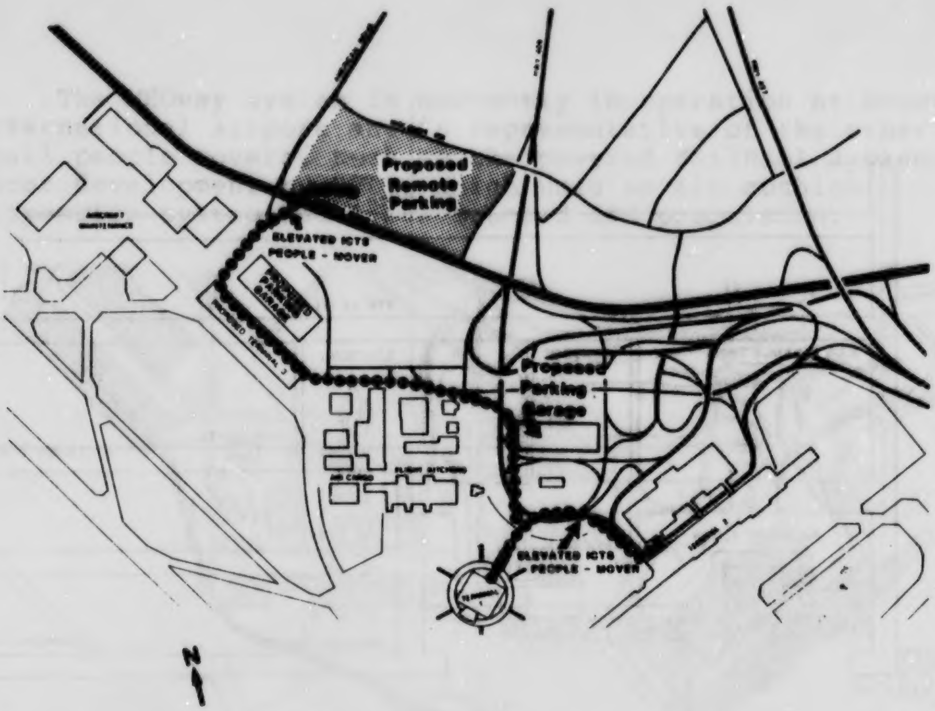

Proposed Remote Parking
ELEVATED ICTS PEOPLE - MOVER
AIRCRAFT MAINTENANCE
PROPOSED PARKING GARAGE
PROPOSED TERMINAL 2
Proposed Parking Garage
AIR CARGO
FLIGHT KITCHENS
ELEVATED ICTS PEOPLE - MOVER
TERMINAL 1
N

Figure 7 ICTS Route at TIA

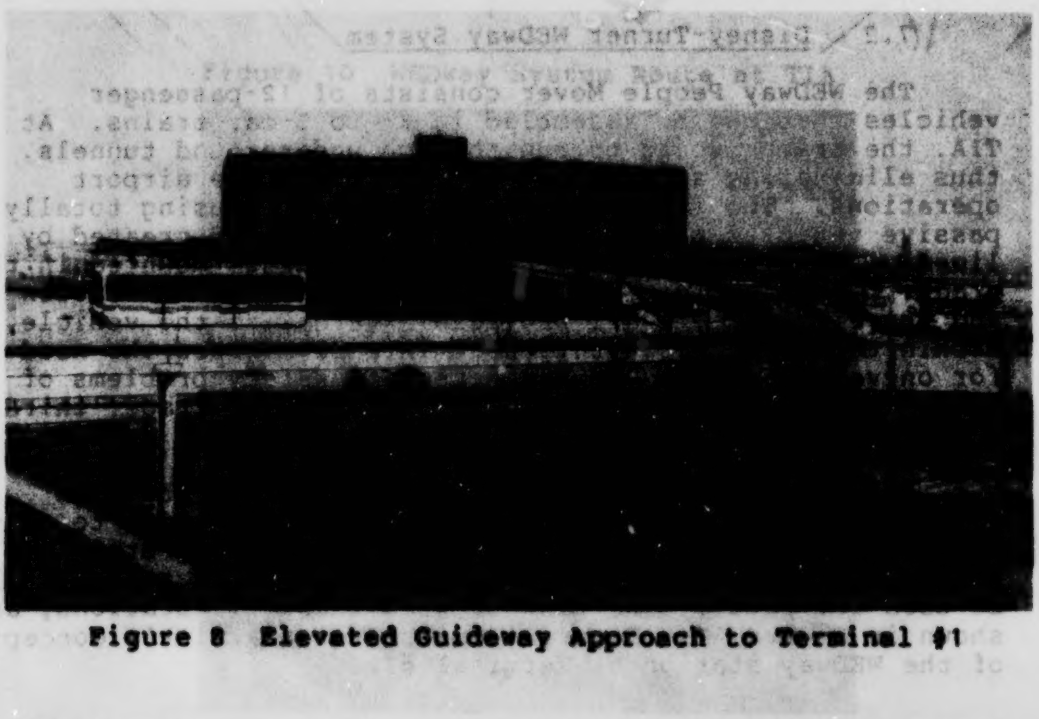


Figure 8 Elevated Guideway Approach to Terminal #1

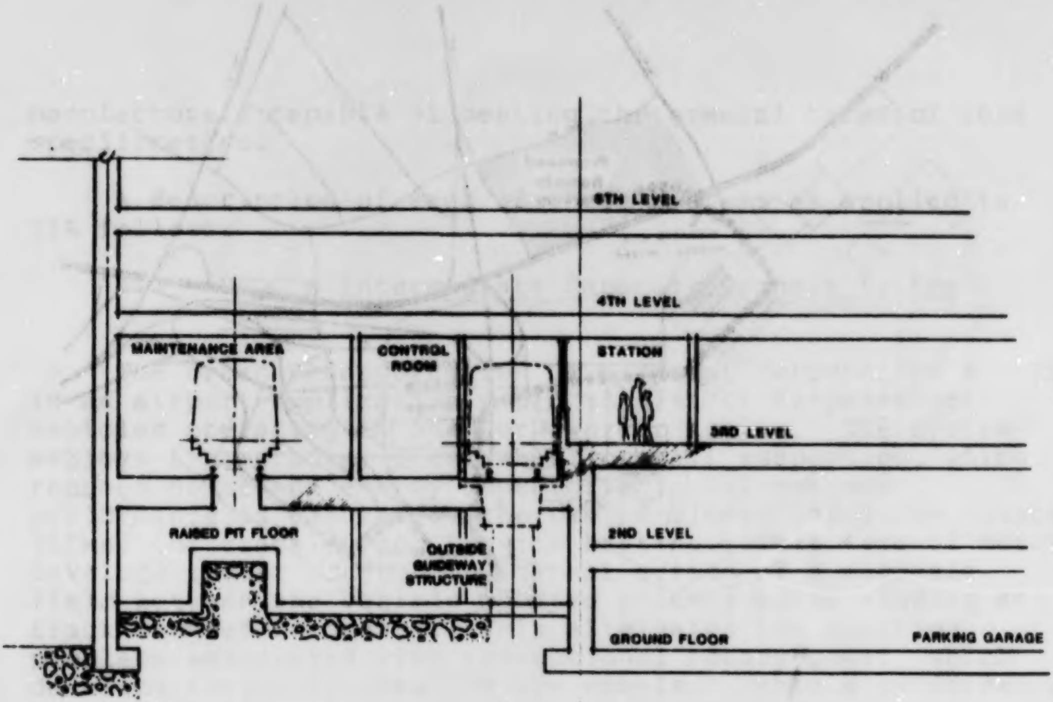

5TH LEVEL
4TH LEVEL
MAINTENANCE AREA
CONTROL ROOM
STATION
3RD LEVEL
RAISED PIT FLOOR
OUTSIDE GUIDEWAY STRUCTURE
2ND LEVEL
GROUND FLOOR
PARKING GARAGE

Figure 9 ICTS Maintenance Area and Parking Garage

7.2 Disney-Turner WEDway System

The WEDway People Mover consists of 12-passenger vehicles that can be assembled in 3- to 5-car trains. At TIA, the trains would be run through underground tunnels, thus eliminating any interference with surface airport operations. The system is elegantly simple, using totally passive vehicles propelled by a magnetic field created by linear induction motors with primary windings mounted in the track. Vehicle lighting, air conditioning, communication and surveillance are all provided external to the vehicle, within the tunnel and stations. This eliminates the need for on-vehicle power and its attendant safety problems of protecting the public from an exposed, high-voltage, third power rail.

A possible route for the WEDway system is shown in Figure 10. This route could ultimately be extended to serve a remote parking facility and/or a rapid transit station. The existing Terminal #1/Terminal #2 pedestrian tunnel would be used for part of the link between these two stations, as shown in Figure 11. Figure 12 presents an artist's concept of the WEDway station at Terminal #3.

The WEDway system is currently in operation at Houston International Airport and is representative of the other small people movers, such as the powered SailRail system under development by UTDC, which uses an air cushion suspension system and track-mounted LIM propulsion.

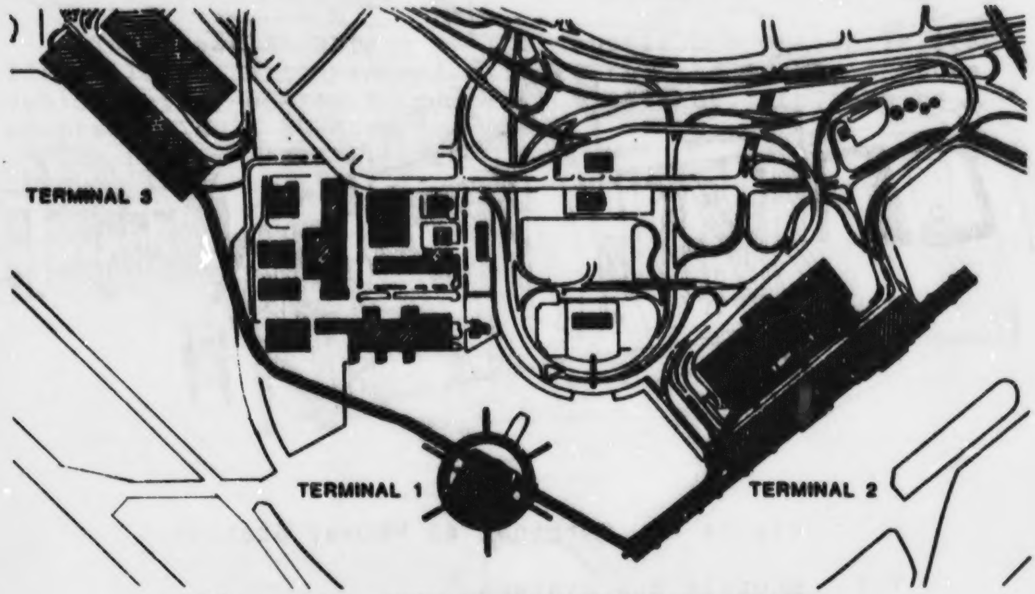


Figure 10 WEDway System Route at TIA

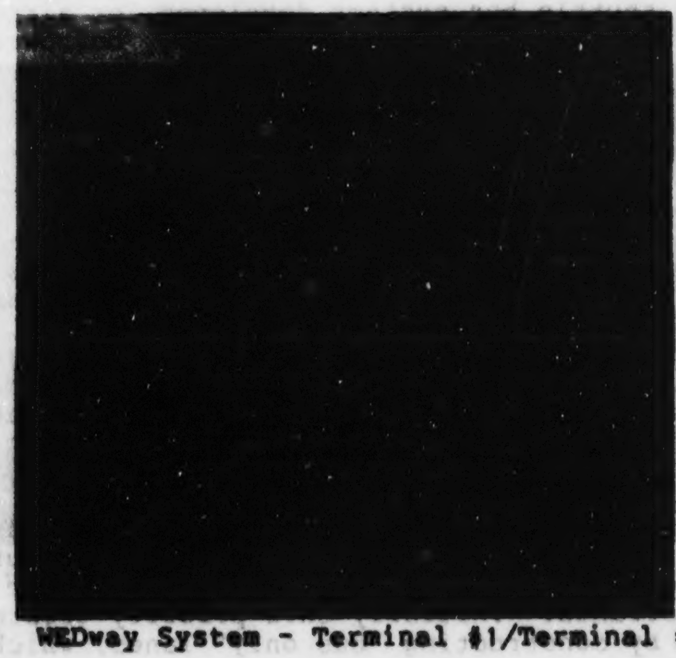


Figure 11 WEDway System - Terminal #1/Terminal #2 Tunnel

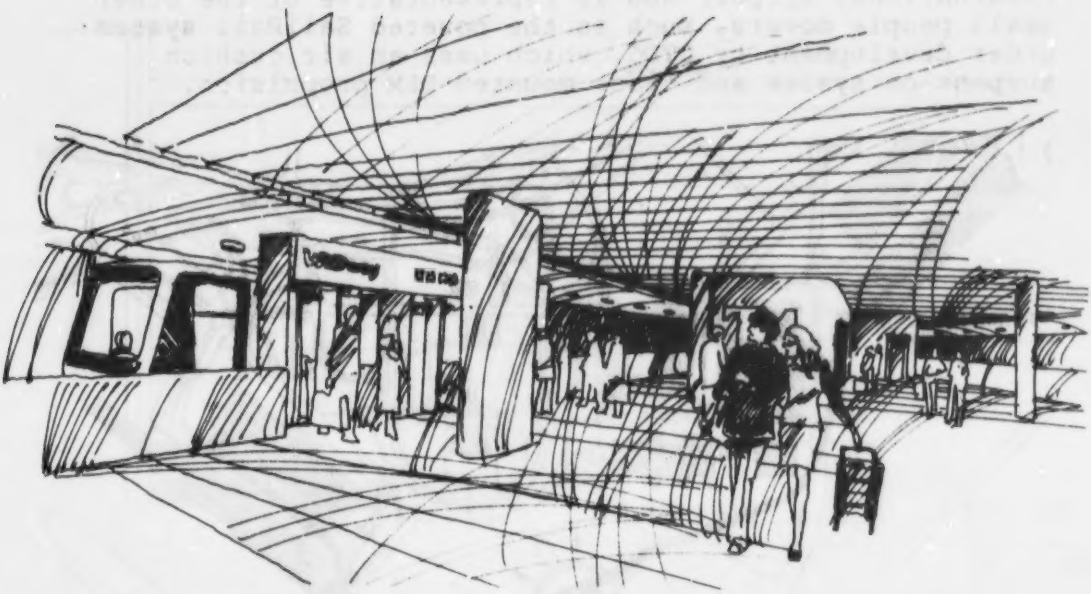


Figure 12 Terminal #3 WEDway Station

7.3 Shuttle Bus Systems

The shuttle bus systems developed for airport applications are essentially technology borrowed from conventional urban transit applications with certain modifications, such as luggage racks, to address special needs encountered at airports.

Two types of bus equipment were found suitable for the TIA airport application; these were:

- the Orion bus - 31-passenger diesel bus
- the GM New Look bus - 53-passenger diesel bus

Both vehicles are used extensively by urban transit authorities across Canada. A Canadian high-capacity bus (80-passenger) is now available from GM; however, the use of this vehicle at TIA has been ruled out owing to anticipated problems with manoeuvrability at Terminal #1.

The operations of the shuttle bus system can be upgraded not only by increasing vehicle size but also by according the shuttle buses priority over other traffic as demand warrants. Initially this priority treatment could be provided by constructing "bus only" lanes, which would allow buses to bypass traffic queues. Ultimately this priority treatment could be extended to the point where the buses operate on a completely dedicated "busway." This could best be achieved at TIA by having the buses operate on the apron, with other airport service vehicles, as shown in Figure 13, entering Terminal #1 by special ramp, as shown in Figure 14.

The great advantage of the shuttle bus option is its flexibility. With minimal difficulty, the system's route, vehicle size, degree of priority treatment, etc, can be adapted to suit changes in demand.

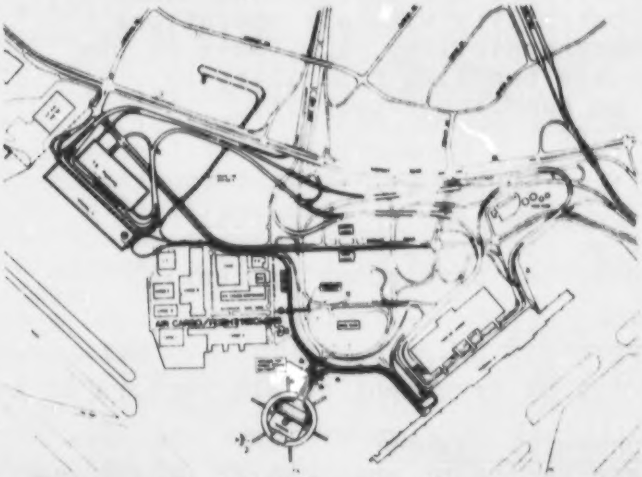


Figure 13 Shuttle Bus Route at TIA

Figure 14 Shuttle Bus System - View From Terminal #1 to Cargo Area

7.4 Decision-Making Tool

Unlike the preliminary evaluation, which examined a range of transportation alternatives but compared them using only a few goals and objectives, this second phase of the evaluation process examined only three alternatives, but compared these using an expanded list of goals and objectives including:

Transportation issues
- compatibility with plans, programs and priorities of the airport and surrounding community
- compatibility with air operations
- comprehensibility, i.e. ease of use
- luggage handling capability
- cargo handling capability
- comfort

Financial issues
- revenue-generation potential
- energy conservation
- industrial development potential

Social issues
- safety and security
- equity of treatment of all sectors of society

Environmental issues
- preservation or enhancement of the quality of life

A second significant difference between the preliminary and the final evaluation is the degree of refinement of the comparison. In the preliminary evaluation simple, qualitative statements of comparison sufficed. In this final evaluation, detailed, quantitative measures of comparison were presented so that the absolute as well as the relative rating of the alternatives was made available to the TIA decision makers.

7.5 Demand-Dependent Factors

Several of the evaluation criteria are dependent on the demands that will be placed on the intra-airport transportation system. The system will have to be sized and configured to serve these demands, and the decisions on layout and capacity will have profound repercussions on such factors as total cost, revenue, energy consumption and environmental conditions. In other words, the greater the demand to be served, the higher will be the impact on cost, energy consumption, etc. The task of this evaluation, however, was to trace out only the transportation implications of the development options for the airport, all of which lead to different demand patterns.

Figure 15 presents a decision tree of the key short- and middle-term development options that influence demand. These options include (from left to right):

- Will a third terminal (T3) be constructed in the short to middle term? It is assumed that if there is a third terminal, a parking garage for users (Pa) and employees (Pe) will be constructed contiguous to this building.
- How will the airlines be allocated among the terminals? Will it be according to a transfer-minimizing strategy (ST) or according to some other plan (AP)? If a third terminal is not constructed, will the airline allocation remain as is, or will the situation be rationalized by shifting traffic from Terminal #1 to Terminal #2?
- Will additional airport user parking be constructed? If so, will it be constructed remotely in the land owned by the airport north of Airport Road (RPu), or in a garage to be located behind the administration building (CPu)?
- Will a hotel be constructed? If so, will it be constructed as part of the land development north of Airport Road (HR), or will it be constructed centrally behind the administration building (HC)?
- Where will the employee parking facilities dislocated by the construction of Terminal #3 be located: north of Airport Road (RPe) or in a central location behind the administration building (CPE)? If a third terminal is not constructed, will any new employee parking be provided?
- Will a central bus terminal be provided? If so, will it be constructed remotely across Airport Road (RGT), as part of the Terminal #3 development (GT3), at the central site behind the administration building (CGT) or at Terminal #2 (GT2)?

Demand information is fundamental to transportation system planning. Ground transportation traffic demands at TIA were forecast for both five-year (1986) and ten-year (1991) planning horizons.

These forecasts were developed using a blend of two methodologies: traffic-flow simulation models (including TIA's Groundside Travel Demand Model-GTDM) that forecast ground traffic volumes at TIA to the end of the planning periods on the basis of air travel patterns, trip frequency and modal choice propensities of airport user-group; and

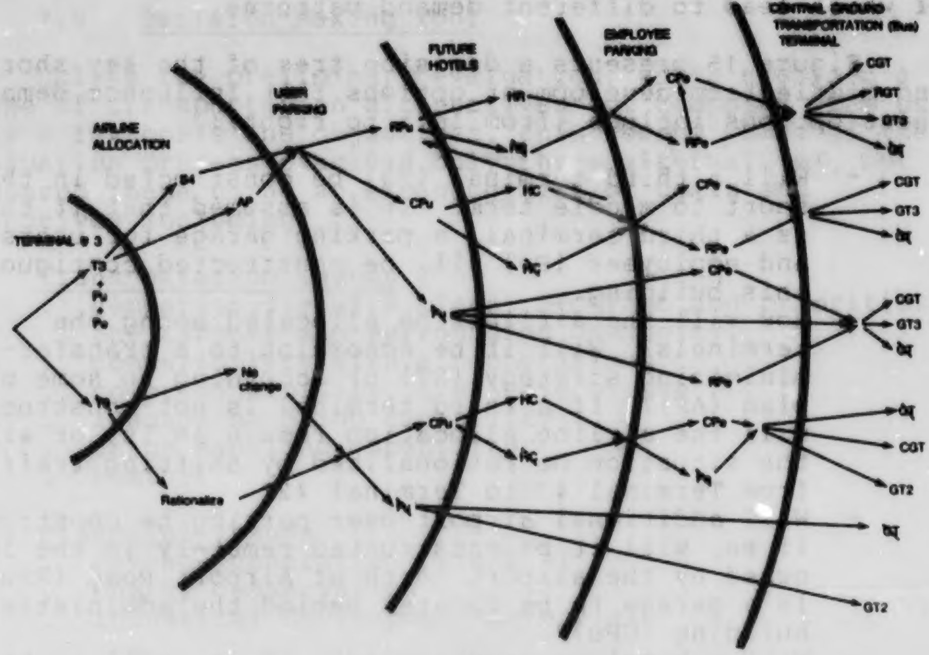

AIRLINE ALLOCATION
USER PARKING
FUTURE HOTELS
EMPLOYEE PARKING
CENTRAL GROUND TRANSPORTATION (Bus) TERMINAL
TERMINAL # 3
T3
S4
AP
No change
Rationalize
RPu
CPu
HR
HC
CPe
RPe
CGT
RGT
GT3
GT2

Figure 15 TIA Decision Tree

second, survey and interview findings obtained by sampling and analyzing airport users' activities during the summer of 1980.

Using two independent approaches in carrying out the demand analysis, one factoring up from the survey findings, the other factoring down from annual data, ground transportation demands for 1986 and 1991 were estimated as shown in Table 1.

Table 1 Estimated Ground Transportation Demand

	1986		1991	
	Low	High	Low	High
Inter-terminal trips				
- Connecting	350	475	525	700
- Originating-terminating	300	325	400	400
- Remote parkers	0	1710	0	3830
Employees	850	870	1075	1060
Transit-transferring	0	1080	0	1360
Hotel	0	500	0	500
Peak-Hour Demands	1500	5000	2000	7850

Since the completion of these demand studies, the forecast for air traffic growth at TIA has been revised downward. These revisions were accommodated in the demand analysis using pivotal analysis, which essentially allows the demand estimates to be reduced proportionally, bringing them in line with the revised forecast of air traffic growth.

Once a path through the decision tree is established, the peak (design) demand on the system can be determined from the forecasts. The system can then be sized to serve the demand at the desired level of service. From the layout distances, number of vehicles, headways, etc., the cost of the service can be determined, emissions and energy consumption estimated, etc. for each candidate system, as these are functions of the type of technology, vehicle-kilometres of service, hours of service, etc.

7.6 Capacity Choice Constraints

A major constraint that must be recognized when evaluating the three candidate technologies is the maximum capacity of each system. This is particularly acute in the case of the shuttle bus where curb occupancy limitations impose a practical minimum headway of two minutes, which means a practical capacity limit of approximately 1500 passengers per hour.

Many of the development options result in demands well in excess of this figure. Therefore, the peak and annual demand forecasts generated by the selection of development options can be used to reduce the number of alternatives by identifying those with insufficient capacity to cope with the peak demand. To assist in this analysis of demand/capacity, and to determine when demand will exceed capacity for each technology given different assumptions on airport growth, a computer program was written to allow TIA planners to specify a development pattern of the airport and from this determine the peak demand volumes that must be served in each year to the planning horizon year. From this program output, it is possible to determine at what point each of the technologies reaches its practical capacity limit, if ever. Airport development plans that generate demands in excess of capacity of a particular candidate system effectively eliminate that system from further consideration.

7.7 Other Choice Constraints

As described in the preceding sections, capacity limitations may reduce the problem of choosing the optimal intra-airport transportation system by eliminating one or more of the alternatives. Capacity, however, is not the only choice constraint; other choice constraints in the TIA case are described below:

- the tunnelled guideway alternative can be eliminated if service must be provided to the area behind the administration building (all branches marked "C" in Figure 15), as this option cannot reasonably be made to service this area owing to topography and to the location of major underground airport services.
- the shuttle bus option can be eliminated if a decision is taken to have a central bus terminal (all branches marked GT in Figure 15) as it is unreasonable to expect commuters to transfer from one bus to another for such a short trip.
- the elevated guideway can be eliminated if peak demand is below 1000 passengers per hour. This technology is over-sophisticated for demand below this level.

Figure 16 illustrates how these constraints can interact to reduce the choice of intra-airport transportation alternatives. At this stage of the analysis, the constraints might restrict the choice to a single system, in which case the analysis is complete and the final choice made. If, however, two or more alternatives remain feasible, the final choice is made by estimating the life-cycle costs of the feasible alternatives, then comparing the incremental cost of choosing a more expensive alternative with the level of service and other advantages purchased by the higher investment.

7.8 Life-Cycle Cost

Since there are so many possible combinations of development options and since life-cycle costs are possibly the single most important decision criterion, the cost analysis element of the evaluation process was addressed by extending the previously described computer program to permit detailed financial analyses of the life-cycle costs of each alternative. With this computer program, the analyst is free to specify: a) the desired land use development pattern; b) the system layout; c) the forecast growth rate for air traffic; and, d) the discount and inflation rate for funds.

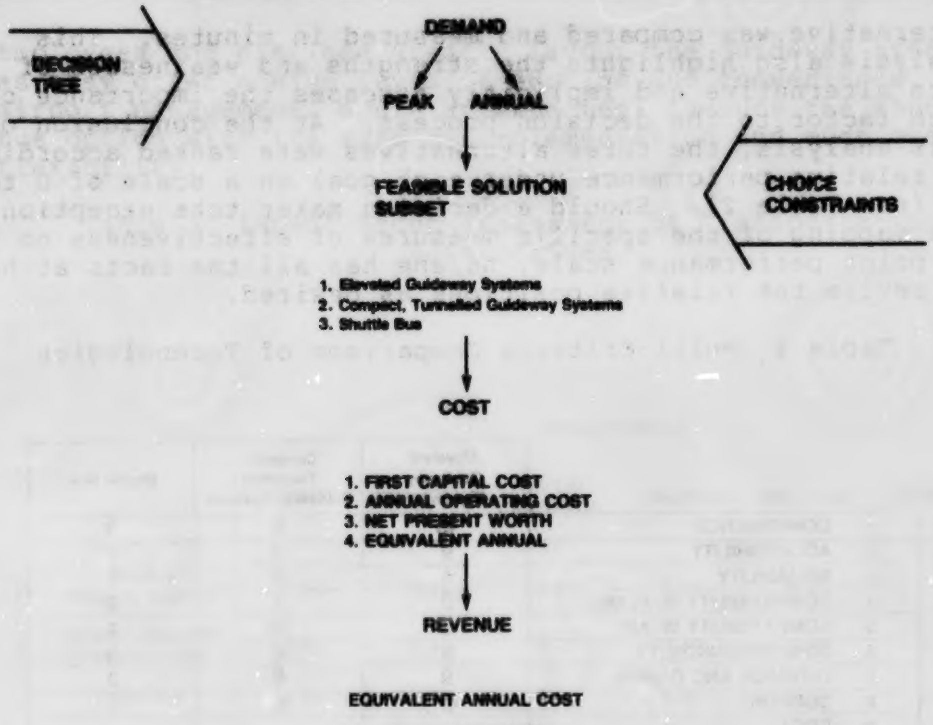

DEMAND
DECISION TREE
PEAK
ANNUAL
FEASIBLE SOLUTION SUBSET
CHOICE CONSTRAINTS
1. Elevated Guideway Systems
2. Compact, Tunnelled Guideway Systems
3. Shuttle Bus
COST
1. FIRST CAPITAL COST
2. ANNUAL OPERATING COST
3. NET PRESENT WORTH
4. EQUIVALENT ANNUAL
REVENUE
EQUIVALENT ANNUAL COST
ANNUAL RIDERSHIPS

Figure 16 Identification of Feasible Alternatives

From this information and the known operating and capital costs of each of the alternatives, the equivalent annual cost and net present worth of each system can be computed over an assumed service life. The program also computes the break-even cost on a per passenger basis, i.e., the passenger revenue necessary to make the system self-supporting.

7.9 Multi-Criteria Comparison

While cost is unquestionably the most important issue facing decision makers, many other factors must be considered in choosing a course of action regarding intra-airport transportation. The majority of these factors cannot be reduced to a single comparable measure, such as dollars, but rather must be compared using a wide range of diverse measures of effectiveness. To present the results of such a multi-criteria evaluation in a manner most useful to decision makers, the performance of each of the candidate systems was first compared in the most detailed and specific (i.e., quantifiable measures) manner possible. For example, under the "convenience" criterion, the travel time of each alternative was compared and measured in minutes. This analysis also highlights the strengths and weaknesses of each alternative and implicitly assesses the importance of each factor to the decision process. At the conclusion of this analysis, the three alternatives were ranked according to relative performance under each goal on a scale of 0 to 10 (see Table 2). Should a decision maker take exception to the mapping of the specific measures of effectiveness on the 10-point performance scale, he/she has all the facts at hand to revise the relative positions as desired.

Table 2 Multi-Criteria Comparison of Technologies

		Elevated Guideway Systems	Compact, Tunnelled Guideway Systems	Shuttle Bus
1.	CONVENIENCE	10	9	3
2.	ACCESSIBILITY	9	3	7
3.	RELIABILITY	4	9	7
4.	COMPATIBILITY W/PLANS	9	3	8
5.	COMPATIBILITY W/AIR	3	10	4
6.	COMPREHENSIBILITY	9	6	3
7.	LUGGAGE AND CARGO	9	6	2
8.	COMFORT	9	10	2
9.	COST			
10.	FLEXIBILITY	2	2	9
11.	REVENUE (COST/PASS.)			
12.	ENERGY	5	5	6
13.	INDUSTRIAL DEVELOPMENT	10	2	3
14.	EASE OF IMPLEMENTATION	3	2	9
15.	SAFETY AND SECURITY	9	10	5
16.	EQUITY	10	9	2
17.	ENVIRONMENT	8	10	2
18.	QUALITY OF LIFE	8	10	4

7.10 Weighted Comparison

Although all measures of effectiveness are relevant, not all have equal weight in the decision process. The weight placed on each criterion depends upon the group assessing it.

In recognition of these differing perspectives, a weighted multi-criteria comparison was carried out. These weightings were based on discussions with each of the impact groups named in section 6.1.

The results of this weighted comparison are presented in Table 3. It is not surprising to see that the users, employees and airlines greatly favour the guideway systems as they offer a high level of service and convenience. The airport management, again as expected, favours the shuttle bus option with its ease of implementation and much greater flexibility.

Table 3 Impact Group Assessment of Transportation Alternatives

		IMPACT GROUP					
		USERS	EMPLOYEES	AIRPORT OPERATOR	AIRLINES	BUS/TAXI	PUBLIC
ALTERNATIVES	Elevated Guideway Systems	7.66	7.11	5.87	5.63	6.47	6.39
	Compact, Tunnelled Guideway Systems	8.68	8.82	5.22	7.49	6.30	5.48
	Shuttle Bus	4.46	4.84	6.47	5.91	5.77	5.78

This weighted comparison can be carried one step further: the importance of each impact group to the decision process can be assessed and the scores for each of the transportation alternatives weighted by this importance factor. Table 4 lists four sets of importance factors assigned to each impact group. Figure 17 presents the effects of each weighting scheme in the ranking of the transportation alternatives. As can be seen, the guideway options are generally favoured when purely non-economic issues (schemes a and b) alone are considered, with the tunnelled system having a slight advantage. If the weight assigned the airport management is increased relative to the other impact groups from 0.4 to 0.7 (scheme d), there is little or no difference between the alternatives from the non-economic perspective.

Table 4 Four Schemes to Assign Weightings of Impact Groups

IMPACT GROUP	WEIGHTING SCHEME a	b	c	d
USERS	0.3	0.25	0.2	0.2
EMPLOYEES	0.1	0.1	0.05	0.05
MANAGEMENT	0.4	0.5	0.6	0.7
AIRLINES	0.1	0.1	0.1	0.05
BUS/TAXI	0.05	0	0	0
PUBLIC	0.05	0.05	0.05	0

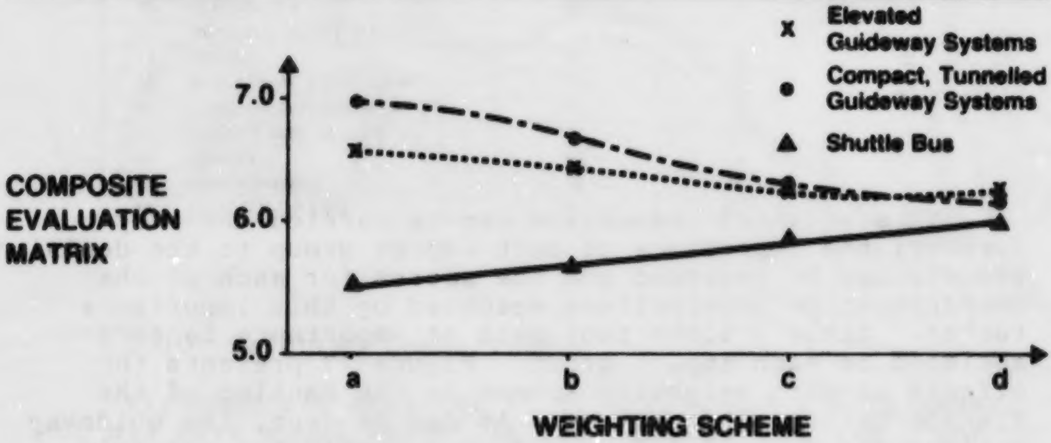


Figure 17 Composite Evaluation Matrix

7.11 Trade-offs between System Cost and Level of Service

While the multi-criteria evaluation does serve to sharpen the focus on the key trade-offs between level of service attributes and system cost, and certainly helps decision makers understand how the various impact groups view the alternatives, it may prove difficult for decision makers to rely solely on it to reach a final decision.

One of the principal reasons that the weighted multi-criteria evaluation is not more conclusive is that certain of these criteria cannot easily be measured using a linear scale. The only true measure is whether or not candidate transportation systems meet certain threshold values. Above this threshold value, degrees of difference in the performance of the systems are of little consequence. Criteria such as comprehensibility, equity and safety fall within this group of threshold sensitive issues. The original process of selecting the three transportation systems virtually ensured, however, that these threshold values would be met. Attention, therefore, needs to be focussed on the criteria that truly distinguish the transportation alternatives. As a final step in this multi-criteria evaluation process, these trade-offs need to be clearly identified to the decision makers.

In the TIA case, the key trade-offs were identified as being:

. Excellent level of service	Versus	. Low cost
. Support of airport development plans		. Flexibility to meet unforeseen changes in demand patterns
. Canadian industrial development		. Ease of implementation

8. CASE STUDIES

In order to bring all of the elements of this analysis together and to illustrate their application as aids to decision making, three case studies were undertaken. In effect, these case studies trace out the ground transportation implications of following three different paths through the decision tree of TIA operating policy and land use development options (Figure 15).

The three paths were selected because they were thought to be of particular interest to TIA planners and represent a range of potential ground transportation demands. It is emphasized that these case studies are only intended to illustrate the application of this analytic technique. The conclusions resulting from the case studies are valid in relation only to the case study in question. The fact that a particular set of development options was chosen in no way represents an endorsement of any one option. The actual selection of a development option will require that a great many factors be considered, not merely ground transportation, the principal concern of this study. With this important note of caution, the results of the case study analyses are as follows:

8.1 Case Study #1 - No Third Terminal, Central Parking Garage (Status Quo)

In this case study, the following development options are assumed:

(a) No third terminal will be built in the short to middle term.

(b) A parking structure will be constructed in the area immediately north of the administration building to handle the Terminal #1 parking shortfall.

(c) No employees will be carried on the intra-airport transportation system. (They will continue to have their own bus service from the north parking lot).

(d) No central (bus) ground transportation terminal will be constructed.

8.1.1 Choice Constraints

The inclusion of a central garage precludes the choice of the tunnelled guideway system as this system cannot serve the area north of the administration building. The choice is therefore reduced to that of the shuttle bus or the elevated guideway system.

8.1.2 Demand/Capacity Constraints

The decision not to proceed with Terminal #3 in the short to middle run implies a fairly pessimistic outlook for future air traffic growth; therefore, a conservative one per cent growth rate was used for this analysis. The dashed line in Figure 18 traces the expected growth in annual demand on a system for this two-terminal/central garage scenario over the planning period. Peak-hour ridership on the critical link between the central garage and Terminal #1 will reach capacity in the first year of service, thus precluding selection of the shuttle bus system, if the 1500 pphpd capacity limit on such a system is assumed.

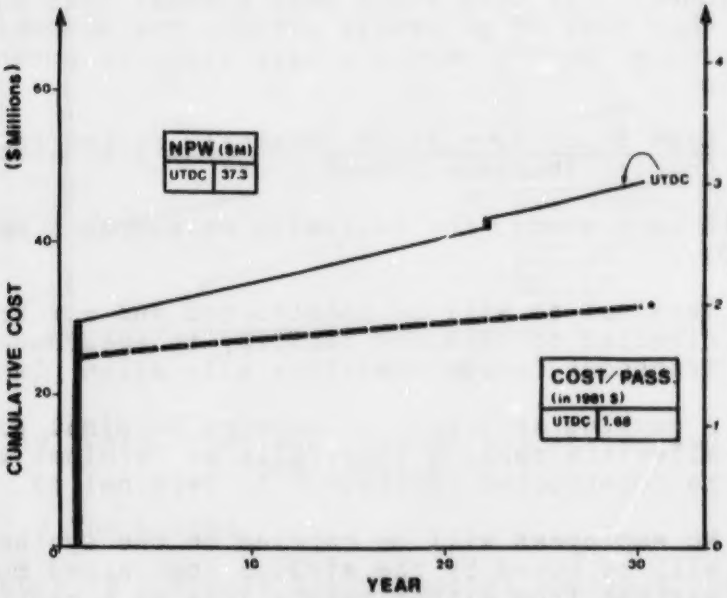


Figure 18 Case Study #1 - Demand Projection and Financial Analysis ($1981)

8.1.3 The Choice

The elimination of the shuttle bus and tunnelled system reduces the courses of action open to the single choice of the elevated guideway alternative. The life-cycle cost of this option (net present worth - NPW) and required revenue per passenger to break even are presented in Figure 18.

This case study clearly illustrates how the combination of a choice constraint, coupled with capacity constraint, can greatly simplify the selection problem.

8.1.4 Discussion

By far the heaviest demand on the system is on the link between Terminal #1 and the central parking garage. Various means of serving this heavy flow can be considered, the most obvious of these being a pedestrian bridge with moving walkways. This option was examined, but it was found that the cost of the moving ways (conveyor equipment) alone would be over 5.5 million dollars. In addition, the bridge would have to be constructed to virtually the same standards as the elevated guideway; it would also have to be heated and air conditioned. All this would mean a total cost equal to or greater than that of guideways without the same high level of service (moving ways are very slow) or potential for expansion.

8.2 Case Study #2 - Third Terminal, No Central Complex (Minimum Demand Case)

In this case study, the following development options are assumed:

(a) Terminal #3 will be constructed and air traffic diverted to this new facility in accordance with Transport Canada's airline allocation plan.

(b) A parking structure to service Terminal #3 and alleviate parking shortfalls at Terminal #1 will be constructed contiguous to Terminal #3.

(c) No employees will be carried on the system; they will be bused by the airline contracted bus systems from either remote lots or a central parking structure for employees.

(d) No central (bus) ground transportation terminal will be constructed.

8.2.1 Choice Constraints

There are no choice constraints in this case; any of the three candidate systems can be considered for this application.

8.2.2 Demand/Capacity Constraints

Recent downward trends in air travel indicate that the original assumption of a 4.6 per cent annual growth rate for air travel is far too high and consequently the more realistic forecast of 3.1 per cent annual growth was used. The dashed line in Figure 19 traces the projected annual increase in ridership over the planning period.

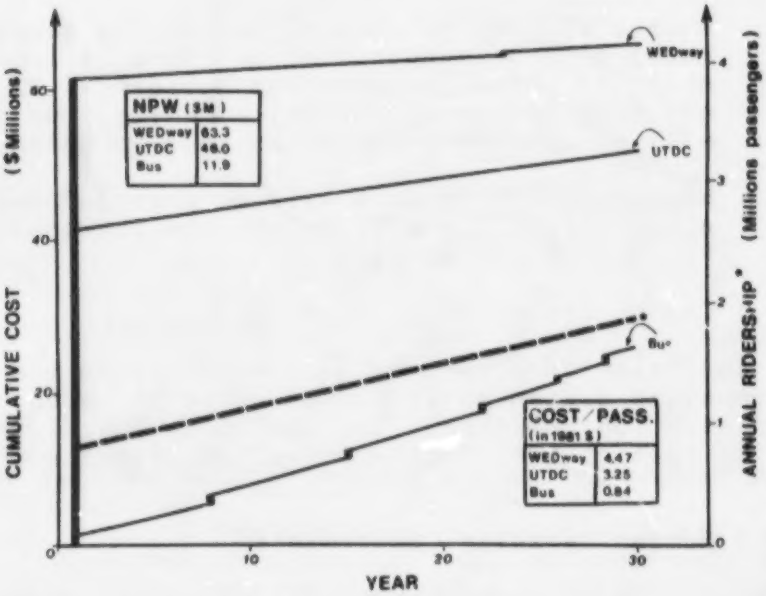


Figure 19 Case Study #2 - Demand Projection and Financial Analysis ($1981)

8.2.3 The Choice

Figure 19 presents the financial analysis for the elevated guideway, the tunnelled guideway and the shuttle bus. As can be seen, the net present worth (NPW) of guideway alternatives is several times that of the shuttle bus. The operational and service advantages of the guideway systems in no way compensate for their much higher life-cycle costs. The only logical choice in this case study is the shuttle bus option, particularly if, in addition to the cost savings, the flexibility and the ease of implementation of the shuttle bus option are considered.

8.3 Case Study #3 - Third Terminal, Central Complex, Remote Parking (Maximum Demand Case)

In this case study, the following development options are assumed:

(a) Terminal #3 will be constructed and traffic diverted to it in accordance with the airlines' preferred plan for carrier allocation.

(b) A parking structure will be constructed contiguous to Terminal #3.

(c) A central complex housing, a parking garage and a hotel will be constructed on the site immediately north of the administration building. If a guideway system is chosen, a central bus terminal will also be constructed at this location.

(d) Employee parking lots will be provided north of Airport Road and serviced by the intra-airport transportation system.

8.3.1 Choice Constraints

The inclusion of a central garage precludes the choice of the tunnelled system as it cannot serve the area north of the administration building. The choice is therefore narrowed to that of the shuttle bus or the elevated guideway.

8.3.2 Demand/Capacity Constraints

As with case study #2, an annual air traffic growth rate of 3.1 per cent is assumed here. The dashed lines in Figure 20 trace the forecast growth in air traffic over the planning period. Based on these levels of demand, the maximum link volumes are such that the shuttle bus will only be capable of coping with demand over the first 10 years of operation, after which time a higher capacity system (e.g. elevated guideway) will be required.

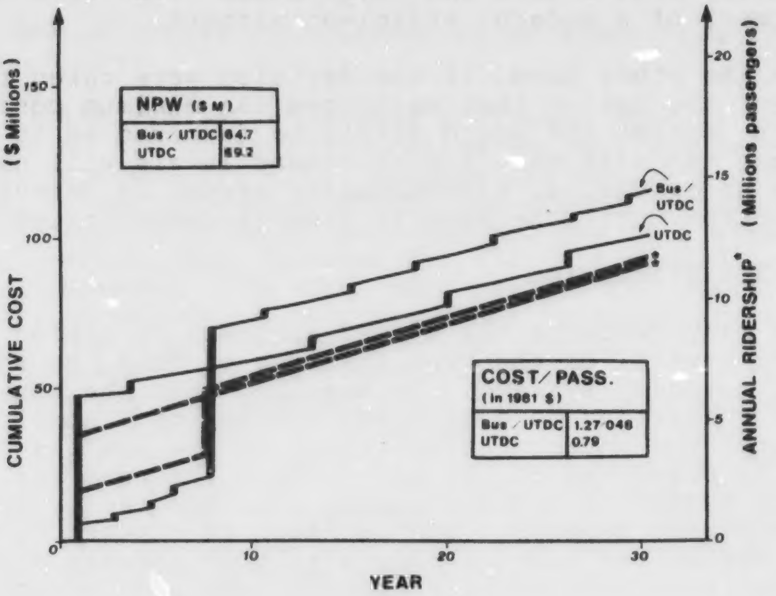


Figure 20 Case Study #3 - Demand Projection and Financial Analysis ($1981)

8.3.3 The Choice

In this scenario, two courses of action are possible:

(a) Opting for the high-capacity, elevated guideway system immediately; this dependsd on whether the added cost of the guideway option is considered justifiable by virtue of the higher level of service and other advantages it affords. The financial implications of such a choice are presented in Figure 20.

(b) Opting for a staged approach in which provision for adding a guideway station would be made in planning Terminal #3, but actual implementation would be deferred as long as possible (i.e., until the shuttle bus system reached capacity and could no longer cope). The financial implications of this phased approach are also shown in Figure 20.

If the decision were made to choose the system that maximizes the maximum possible benefits, option (a) would likely be favoured as it presents the best opportunity to comfortably meet demand and forge ahead with the continued development of a modern, efficient airport.

On the other hand, if the decision were taken to implement the system that maximizes the minimum possible benefits, option (b) would likely be favoured as it minimizes the risk that future demand levels will not justify an expensive, high-capacity system by deferring its construction until the need is clearly demonstrated.

8.3.4 Discussion

In many respects the staged approach of option (b) combines several of the best features of both the shuttle bus and guideway systems. By starting with the shuttle bus, and not converting to a guideway system until absolutely necessary, the inherent flexibility of the shuttle bus option is preserved to the point where the need for a guideway system is unquestionably demonstrated by actual (not forecast) demands. The decision to convert to the more costly system can then be made with much greater confidence. The long-term costs of this approach are also minimized in that the large initial capital required of the guideway system is postponed for as long as possible. The long-term development interests of the airport are served by the fact that provision is made from the outset to convert to the guideway system, if and when it is justified.

9. CONCLUSIONS AND RECOMMENDATIONS

The principal conclusions to be drawn from this research are:

a) The evaluation method presented here is intended as an aid to decision making on land use development options for TIA. It provides decision makers with a clear understanding of the ground transportation implications of pursuing any one of a wide range of development options for TIA. It should be stressed, however, that this tool assists the decision maker in selecting an appropriate transportation system for a specific development option. In order to compare alternative development/transportation scenarios, the scope of the exercise would have to be considerably expanded to include other aspects of airport operations. It should also be noted that information on non-user impacts (e.g. traffic congestion of development options) is not currently available, and thus should be accounted for in the decision process separately.

b) The results of the evaluation of the three case studies present an interesting anomaly. Originally this study was undertaken because it was believed that the introduction of a third terminal would magnify the ground transportation problems (particularly inter-terminal transfers) to the point where a more sophisticated intra-airport transportation system would be required. As case study #2 demonstrates, however, if a large capital investment is made in a third terminal, a self-contained facility designed to relieve the congestion at Terminal #1, then there is little or no justification for a large investment in an intra-airport transportation system as inter-terminal transfers will be minimal. If, on the other hand, no third terminal is to be constructed in the short to middle run (case study #1) and every effort is made to optimize the use of the existing facilities at TIA, then the capital investment in a high-capacity, high-performance system, i.e. an elevated guideway system, is required and justifiable. The high-performance elevated guideway system ensures that the available groundside capacity at Terminal #2 can be mobilized in support of Terminal #1. It also ensures that adequate capacity and level of service can be provided on the critical system link between Terminal #1 and the central parking structure required to alleviate the parking shortfall at Terminal #1.

c) As case study #3 demonstrates, in the three-terminal scenario, a high-performance intra-airport transportation system will be required if the airlines' preferred plan for carrier allocation among the terminals is adopted, if the system is to carry employees and if a central bus facility is to be constructed. In other words, with the three-terminal case, the investment in a high-performance guideway system can be justified if certain policy decisions regarding employees, transit access, etc., are adopted.

d) The design of any intra-airport transportation system should have provisions for retrofitting a guideway at a later date. To facilitate such an eventuality, Terminal #3 can be designed to accommodate a roof-level guideway station in the future (i.e. column-strengthened space for escalators provided, etc.). This move will preserve maximum flexibility to adapt to future developments at TIA. With this provision for the eventual addition of a guideway system, a phased, minimum-risk approach to the intra-airport transportation problem can be adopted, which begins with the use of an improved shuttle bus service and only commits to the guideway system when actual demand demonstrates the need. A tunnelled guideway system would not be as easy to phase in.

Based on these conclusions, the following recommendations are made:

a) It is apparent that the manner in which activity patterns develop at TIA will profoundly influence future intra-airport transportation requirements. Thus, the ultimate choice can only be made in the context of other decisions concerning the development and location of other major airports. Accordingly, further evaluation of intra-airport transportation requirements must be carried out in the broader airport planning context. It is only in this context that a better perspective can be gained on the intra-airport transportation costs in relation to the costs and benefits associated with the other components of the entire airport complex.

b) If a guideway system is required either to make a two-terminal airport feasible over the middle run, or to connect a three-terminal airport, the next step in the process should be to develop requirements for this system so that competitive bids can be solicited. To the maximum extent possible the civil structures for such a system should be specified in such a way as to allow more than one supplier to install their system on it. This will improve Transport Canada's control of the system supplier to ensure adherence to the performance requirement.

c) An analysis of road traffic conditions should be carried out using the 1980 data and revised Ground Transportation Demand Model to evaluate the non-user impacts of the various development options being considered by the airport planning staff.

d) The conclusions presented in this study must be considered in conjunction with the traffic engineering analysis, airside capacity analysis and terminal needs analysis to evaluate the full range of options open to the airport. A balanced approach must be sought under which all opportunities and constraints are considered and an optimal, staged approach to the further development of TIA is pursued.

TIA Study Reports

TP #	TITLE	DATE
3129E	Interim Report No. 1 (Strategic Options and Evaluation Methods)	August 1980
23/4/81 ✓2985	Technical Working Paper No. 3 Airport Access Plan Review	March 1981
3046E	Technical Working Papers No. 4 and No. 8 Demand Analysis	October 1981
3047	Technical Working Paper No. 5 Circulation System Alternative	May 1981
3048E	Technical Working Paper No. 6 Literature Review and Site Visit Reports	April 1981
3049	Technical Working Paper No. 7 Preliminary Evaluation of Technical Alternatives	July 1981
2987	Interim Report No. 2 Access Plan Review and Technology Evaluation	October 1981
2939	Technical Working Paper No. 9 Parking Options Analysis	March 1981
✓3621E	Interim Report No. 3 Parking and Ground Transportation Options	March 1982
3162	Technical Working Paper No. 11a Shuttle Bus System Layout & Design	September 1981
3226E	Technical Working Paper No. 11b ICTS Layout & Design	August 1982
3227E	Technical Working Paper No. 11c (WEDway Layout & Design) Two volumes	November 1981

3228	Technical Working Paper No. 11d Westinghouse People Mover Layout and Design	October 1981
3907E	Technical Working Paper No. 12 Impact Group Evaluation Criteria	September 1982
3696E	Technical Working Paper No. 13a Facilities Impact & Architectural Requirements - WEDway & Shuttle Bus	July 1982
3695	Technical Working Paper No. 13b Facilities Impact and Architectural Requirements - ICTS	September 1982
✓ 3906E	Technical Working Paper No. 14 Technology Evaluation	October 1982
✓ 3890E	TIA Intra-Airport Transportation Study Final Report	October 1983
3905E	TIA Intra-Airport Transportation Study Summary Report	October 1983

Transport Canada Transports Canada

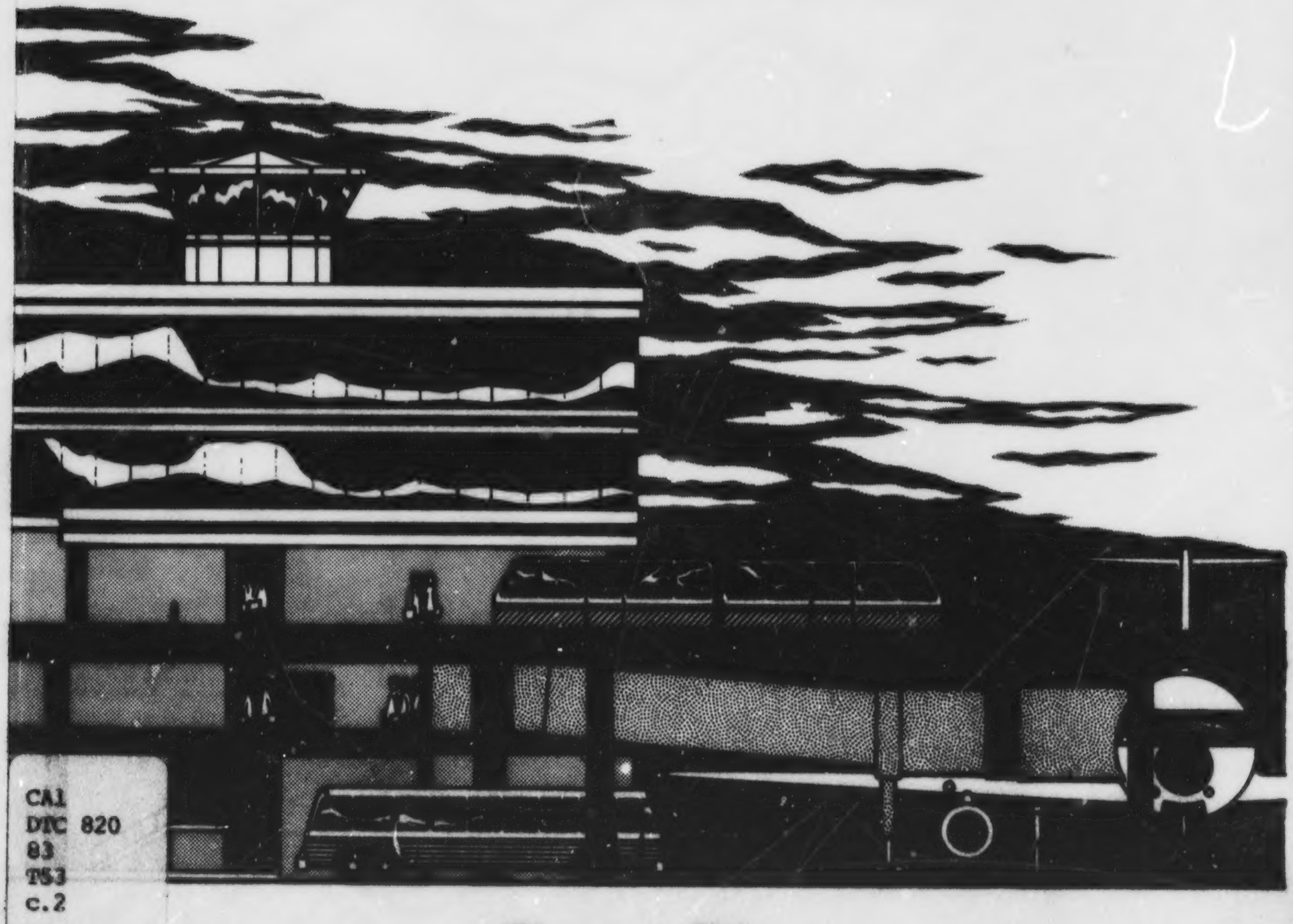
TP 3890E

TORONTO INTERNATIONAL AIRPORT
Intra-Airport Transportation Study

Transportation Development Centre

FINAL REPORT

October 1983



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85-3972/

TP 3890E

Library and Information Centre
Centre de Documentation (GSL)
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OCT 15 1984
Government Publication Officielle
Transport Canada / Transports Canada

TORONTO INTERNATIONAL AIRPORT INTRA-AIRPORT TRANSPORTATION STUDY

FINAL REPORT

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Transportation Development Centre

Montreal, Quebec

October 1983

REPORT DOCUMENTATION FORM

1. Transport Canada Report No. TP 3890E	2. TDC Project No. 4417, 4418, 4419	3. Recipient's Catalogue No.
4. Title and Subtitle Toronto International Airport Intra-Airport Transportation Study - Final Report		5. Report Date October 1983 6. Performing Organization Report No. TP 3890E
7. Author(s) L.A. McCoomb, T.N. Smith, L. Suen, J. Udell		8. Transport Canada File No. D 1455-134-1
9. Performing Organization Name and Address Transportation Development Centre 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3		10. DSS File No. 11. DSS or Transport Canada Contract No.
12. Sponsoring Agency Name and Address Transportation Development Centre 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code TDC 4417, 4418, 4419
15. Supplementary Notes A summary of this report is available in both official languages (TP 3905E and TP 3905F).		16. TDC Project Officer L. Suen, L.A. McCoomb

17. Abstract

This report describes the results of a study by the Transportation Development Centre to evaluate the intra-airport transportation requirements of Toronto International Airport (TIA) to the year 2,000 and beyond, and to develop technical alternatives to meet these requirements. The nature of the intra-airport problem at TIA is reviewed, namely inter-terminal transfers, traffic congestion and access to parking, accommodation and public transit. The report outlines the systems analysis approach used to address these problems and describes the three alternatives selected for detailed evaluation by TIA, namely an intermediate-capacity elevated guideway system, a tunnelled light guideway system and a conventional shuttle bus system. The final section of the report describes the procedure for determining the technical alternative best suited to each of the TIA land use development options. One interesting conclusion of the study is that the expansion to a three-terminal airport configuration will not necessitate the high-technology guideway circulation system; whereas, if a new remote parking facility is added to the current two-terminal airport configuration, the high-technology, intermediate-capacity guideway system will be required.

18. Key Words Toronto, Airport, Terminal, Planning, Intra-Airport, Transport	19. Distribution Statement Copies available from Transportation Development Centre.

20. Security Classification (of this report) Unclassified	21. Security Classification (of this page) Unclassified	22. No. of Pages 128	23. Price NIL

TDC COT 79-005

FORMULE DE DOCUMENTATION POUR RAPPORT

1 Nº du rapport Transports Canada
TP 3890E

2. Nº de l'étude — CDT
4417, 4418, 4419

3 Nº de catalogue du destinataire

4. Titre et sous-titre
Toronto International Airport Intra-Airport
Transportation Study - Rapport final

5 Date du rapport
Octobre 1983

6. Nº du rapport de l'organisme exécutant
TP 3890E

7. Auteur(s)
L.A. McCoomb, T.N. Smith, L. Suen, J. Udell

8. Nº de dossier Transports Canada
D 1455-134-1

9. Nom et adresse de l'organisme exécutant
Centre de développement des transports (CDT)
1000 o. rue Sherbrooke
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10. Nº de dossier — ASC

11. Nº de contrat — ASC ou Transports Canada

12. Nom et adresse de l'organisme parrain
Centre de développement des transports (CDT)
1000 o. rue Sherbrooke
Suite 2421
Montréal, Québec H3A 2R3

13. Genre de rapport et période visée
Rapport Final

14. Code de l'organisme parrain
CDT 4417, 4418, 4419

15. Remarques additionnelles
Un sommaire de ce rapport est disponible dans les deux langues officielles (TP 3905E et TP 3905F)

16. Agent de projet — CDT
L. Suen, L.A. McCoomb

17. Résumé

Ce rapport décrit les travaux d'une étude conduite par le Centre de développement des transports en vue de définir les besoins de l'Aéroport international de Toronto (AIT) pour un réseau de transports aéroportuaires en l'an 2,000 et plus loin, et de trouver les solutions techniques correspondantes. Il passe en revue la nature du problème soulevé par l'Aéroport et, notamment, les déplacements entre aérogares, la densité du trafic et l'accessibilité des stationnements, des hôtels et des services de transport collectif. Il décrit aussi l'approche systémique utilisée pour s'attaquer au problème et esquisse les trois filières retenues qui doivent faire l'objet d'études plus poussées: un système à capacité intermédiaire à voie surélevée, un système de transport léger en tunnel et une navette routière de type classique. La dernière partie du rapport est consacrée à la description de la méthode utilisée pour déterminer l'option la plus avantageuse pour chacun des scénarios envisagés par l'Aéroport en matière d'occupation des sols. Une constatation intéressante de l'étude a été qu'on pourrait ne pas faire appel au système à voie surélevée (option à technologie de pointe) si on dotait l'aéroport d'une troisième aérogare, tandis que si on adjoignait aux deux aérogares existantes un terrain de stationnement éloigné, un tel système deviendrait indispensable.

18. Mots-clés
Aéroport international de Toronto. Aérogare. Planification. Transports aéroportuaires.

19. Diffusion
Le CDT dispose d'un certain nombre d'exemplaires.

20. Classification de sécurité (de ce rapport)
Non classifié

21. Classification de sécurité (de cette page)
Non classifiée

22. Nombre de pages
128

23. Prix
Aucun

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the advice and assistance provided by the Project Team for this work. The contribution of consultants on various aspects of the study is also recognized.

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SUMMARY

In 1980 the planning staff of Toronto International Airport asked the Transportation Development Centre of Transport Canada to study the intra-airport transportation requirements at the airport to the year 2000, and to develop and assess alternative plans to meet these requirements. The need for this study was precipitated by the planning of a third terminal at the airport, which, once it is completed, will increase the number of inter-airline transfers. The Transportation Development Centre was asked to develop an analytical tool and method to assess the transportation system options for connecting the key airport activity centres.

In addition to serving inter-terminal transfers, an improved intra-airport transportation system would: (1) reduce the problems caused by severe traffic congestion on the airport road system, particularly on the approach to Terminal 1; (2) help to ease the parking shortage at Terminal 1, which will be aggravated by the construction of Terminal 3; (3) improve the productivity of the regional bus systems now serving the airport by centralizing their operations; (4) promote a shift to transit for airport employees and users by providing a high-quality connection between the airport's activity centres and the proposed rail transit link; and (5) serve an airport hotel, should one be built.

To ensure a proper balance, this study was carried out in concert with other key airport planning activities, namely: the airport master plan, the airside capacity plan, the Terminal 3 plan (beginning with the optimization study of Terminals 1 and 2), and the Metropolitan Toronto rapid transit expansion plan.

Because of the wide range of possible alternatives (including technologies, system layouts, and modes of operation) for an improved intra-airport transportation system, the study was conducted in two phases. The first phase examined transportation system alternatives using seven critical criteria: (1) life-cycle cost; (2) convenience to users; (3) accessibility to airport activity centres; (4) reliability; (5) ease of implementation; (6) flexibility to meet unforeseen changes in demand; and (7) environmental impact. This first-phase evaluation provided a shortlist of three technology alternatives, each of which is optimal over a particular range of applications to the airport. These alternatives are:

- Elevated Guideway Systems: For high-demand situations (1,500-5,000 passengers per hour per direction [pphpd]) using large (60-120 passenger) electrically powered trains, e.g. UTDC or Westinghouse operating on an elevated, concrete guideway.

- Tunnelled Guideway Systems: For medium-demand situations (500-2,000 pphpd) using small (36-60 passenger), automated, electrically powered trains, e.g. WEDway operating in a tunnel.

- Shuttle-Bus System: For low-demand situations (0-1,500 pphpd), using conventional (35-50 passenger) diesel transit buses operating on priority or dedicated rights-of-way.

Demand estimates were prepared from nominal schedules for the years 1985, 1991, and 2000. From these, peak-hour and annual ridership estimates were formulated for each potential land-use development and/or policy option. Phase two of the study set out to determine which of the candidate transportation systems identified in phase one would best serve each of the operating policy and land-use development options and, in so doing, to trace out the intra-airport transportation implications (i.e., required capacity, level of service, cost, etc.) of each of these options.

A greatly expanded list of criteria was considered in the second phase of the analysis, including: comfort, safety and security, luggage and cargo handling capability, equity, and energy consumption. Functional designs were produced for each of the technology alternatives, defining routes, station locations and layouts, operating schedules, etc.

A computer model was developed to assist in the evaluation. By specifying the anticipated annual growth rate for air traffic, the desired land-use development plan, the transportation system, the discount and inflation rates, the expected useful life of equipment, maximum capacities, minimum policy headways, and hours of peak and off-peak operation, the project team determined the life-cycle costs and level-of-service parameters for the three technology alternatives.

This study provides a tool to help decision-makers evaluate development options. Because there are so many options, it was not practical to evaluate them all. Instead, three options of particular interest to the airport planning staff were analyzed as case studies.

Case Study 1

This assumed an annual passenger growth rate of 1 per cent and therefore does not provide for a third passenger terminal in the short or medium term.

This also assumed that a central parking garage will be built north of the administration building to accommodate existing and future shortages at Terminal 1. No provision is made for employees to use the transportation system, nor for a centralized ground (bus) transportation terminal.

Case Study 2

This assumed an average annual growth rate of 3.1 per cent and that a third terminal (with parking garage) will be built. As with Case Study 1, no provision is made for employees to use the transportation system, nor for a centralized ground transportation terminal.

Case Study 3

This assumes the same annual traffic growth rates and passenger terminal configuration as in Case Study 2. In addition, it assumes that a central ground transportation terminal and a parking and hotel complex will be built north of the administration building. Provision is also made to accommodate airport employees on the system.

Four conclusions were drawn from this study:

1. This study provides decision-makers with a clear understanding of the ground transportation implications of pursuing any one of a wide range of development options for Toronto International Airport. It assists decision-makers in selecting an appropriate transportation system for a specific development option. Information about the impact of non-user, (e.g., traffic congestion) on the development options is not currently available, but it must be accounted for in the decision process.

2. If a third terminal is not built in the short to middle term (Case Study 1), and every effort is made to optimize the use of the existing facilities, then the capital investment in an elevated guideway system is both required and justified. A guideway system would ensure that the available groundside capacity at Terminal 2 can be mobilized in support of Terminal 1. It would also ensure that adequate capacity and level of service can be provided on the

critical link between Terminal 1 and the central parking garage required to accommodate the parking overflow at Terminal 1.

3. If a large capital investment is made in a self-contained third terminal (Case Study 2) designed to relieve the congestion at Terminal 1, then there is little or no justification for large investment in an intra-airport transportation system because inter-terminal transfers will be minimal.

4. A high-performance intra-airport transportation system will be required if a third terminal is built and (1) the airlines' preferred scenario for carrier allocation to the terminals is adopted; (2) the transportation system is to carry employees; and (3) a central (bus) ground transportation terminal is built. In other words, with three terminals, the investment in a guideway system can be justified if certain policy decisions are made about employee use, access, etc. (Case Study 3).

The conclusions of this study must not be considered in isolation. Rather, they must be assessed in conjunction with the traffic engineering analysis, the airside capacity analysis, and the terminal needs analysis, in order to evaluate the full range of options open to the airport. A balanced approach must be sought under which all opportunities and constraints are considered and an optimal staged approach to the future development of Toronto International Airport is pursued.

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1. INTRODUCTION

1.1 History of the Project

In September 1979, the Southern Ontario Multimodal Passenger Study[1] stated that the Toronto International Airport (TIA), Malton, would have to decide quickly how to develop additional airport capacity, due to projected traffic growth and the decision to abandon plans for the Pickering Airport. This spurred TIA to begin planning how to meet southern Ontario's foreseeable air travel demands over the next decade.

In 1980 TIA began two major planning projects: developing an airport master plan and developing conceptual plans for additional airport facilities, including an optional new third terminal. It decided to consult air carriers, municipal and provincial authorities, other interested parties, and the public in developing these plans.

TIA staff realized at the outset that to operate efficiently, an airport must balance the capacities of its runway, terminal, and ground transportation systems. Adding a third terminal at TIA would result in more inter-terminal transfer trips, the need to balance parking supply and demand at each terminal, reduced operating efficiency of such ground transportation as regional bus lines, and the need to balance traffic flow. Various transportation technologies therefore had to be planned, designed, and evaluated for their application at TIA.

In planning how to expand its terminal facilities, TIA needed to anticipate and accommodate ground transportation requirements. In April 1980, TIA asked the Transportation Development Centre (TDC) to study how to resolve the inter-terminal transfer problem and related traffic and parking problems. TDC accepted the task and began its study in August 1980. Since then, TDC has produced fifteen working papers and three interim reports, culminating in this final report and the companion summary report. TDC spent two-and-a-half person years of staff time and a consulting budget of $100,000 in completing this study. Appendix A lists the titles of the working papers and reports.

---

[1] Transport Canada and Ontario Ministry of Transportation and Communications. Southern Ontario Multimodal Passenger Study. September 1979.

1.2 Work Statement

The objective of the study, agreed to by TIA and TDC, was: "To evaluate the need for an intra-airport transportation system and to develop alternative plans to meet related travel demand at TIA to the year 2000 and beyond." The intra-airport transportation system includes vehicle parking, intra-airport circulation, and airport access. Figure 1.1 conceptualizes the scope of the study.

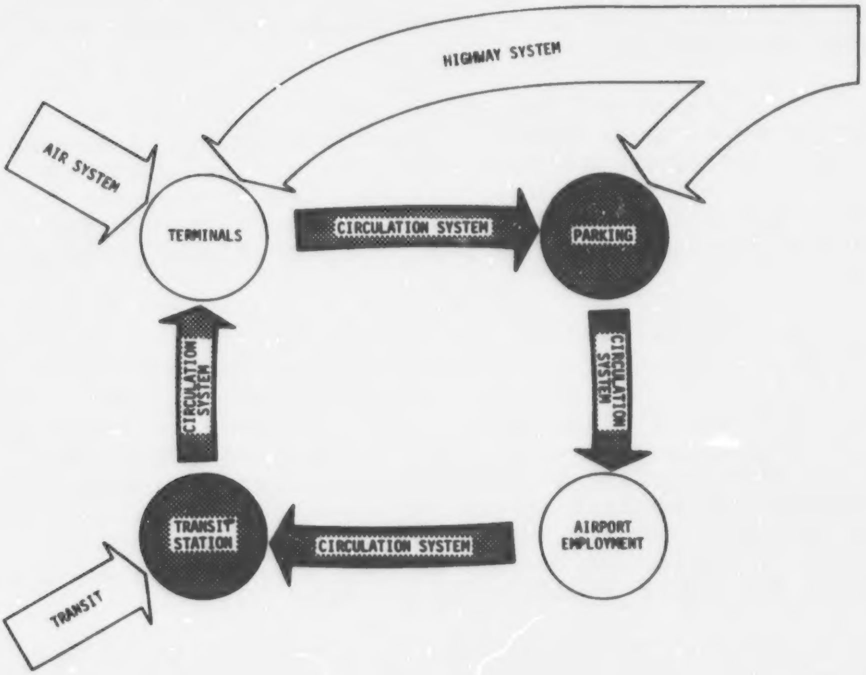

HIGHWAY SYSTEM
AIR SYSTEM
TERMINALS
CIRCULATION SYSTEM
PARKING
CIRCULATION SYSTEM
CIRCULATION SYSTEM
AIRPORT EMPLOYMENT
TRANSIT STATION
CIRCULATION SYSTEM
TRANSIT

Figure 1.1 Scope of the Study ■

The study was divided into four stages:

I) Planning

The planning phase of the work involved:

- identifying problems and strategic issues;
- calculating and analysing existing and projected numbers of air travellers (originating, terminating, and connecting passengers, as well as greeters and well-wishers) and their future inter-terminal travel patterns;

- calculating existing and projected numbers of airport employees (air passenger-related, administration, maintenance, cargo, mail, etc.);
- analysing parking facility options and calculating airport parking requirements, including movements between car-parks and various activity centres;
- defining options for improving ground traffic, including a ground transportation terminal;
- exploring potential rapid transit connections between Toronto and TIA, and protecting right-of-way options.

These preliminary studies helped determine the requirements for an intra-airport transportation system.

II) System Selection

Alternative transportation systems were identified to serve the needs of the airport. These included pedestrian systems, a shuttle bus, and group rapid transit. A preliminary screening shortlisted the most relevant technologies. These in turn were analysed for their alignments and modes of operation, based on projected demand, and for their architectural requirements.

III) Evaluation

The alternative technologies were evaluated, alone and in various combinations, to see how well they would meet a predetermined set of goals and objectives. These goals and objectives, established by the project team, were divided into two tiers. The upper tier contains primary goals and objectives. These represent fundamental criteria which candidate systems must meet in order to be retained for further analysis. The lower tier contains secondary goals and objectives. These represent desirable criteria which shortlisted candidate systems should meet if they are to be considered as a final choice. Each goal had clearly defined objectives with quantifiable measures of effectiveness. The study also considered how changes to the airport's transportation systems would affect six groups: Transport Canada, airport users, airport employees, airline operators, ground transportation operators, and the public, represented by other levels of government.

IV) Recommendations

Scenarios were created to illustrate a narrow range of recommended technologies, and a decision tree and computer program were designed to help evaluate revised options should the assumptions of this study change.

The four stages of the study were further divided into sixteen tasks for project control purposes. These were:

1. Goals
2. Criteria
3. Access
4. Data
5. Technology Shortlist
6. Literature Search and Site Visits
7. Preliminary Evaluation
8. Demand Analysis
9. Parking
10. Traffic Engineering
11. Sketch Planning of Alternatives
12. Simulation
13. Facilities Impact
14. Technology Evaluation
15. Recommendation
16. Implementation Plan

Appendix B explains how the project team was organized.

1.3 Study Approach

Figure 1.2 shows the team's relationship to other groups involved in the study and how it gathered the data.

1.4 Context and Constraints

Since the configuration and technology of TIA's transportation system both depend upon and affect the planning of all airport activity centres, it was crucial for the current study to interface closely with the master plan for the airport, and with the plans for the third terminal and the rapid transit link to Toronto. The project team conscientiously exchanged information and ideas with the groups handling these other three planning activities, so that the recommendations would be consistent with other plans for the airport.

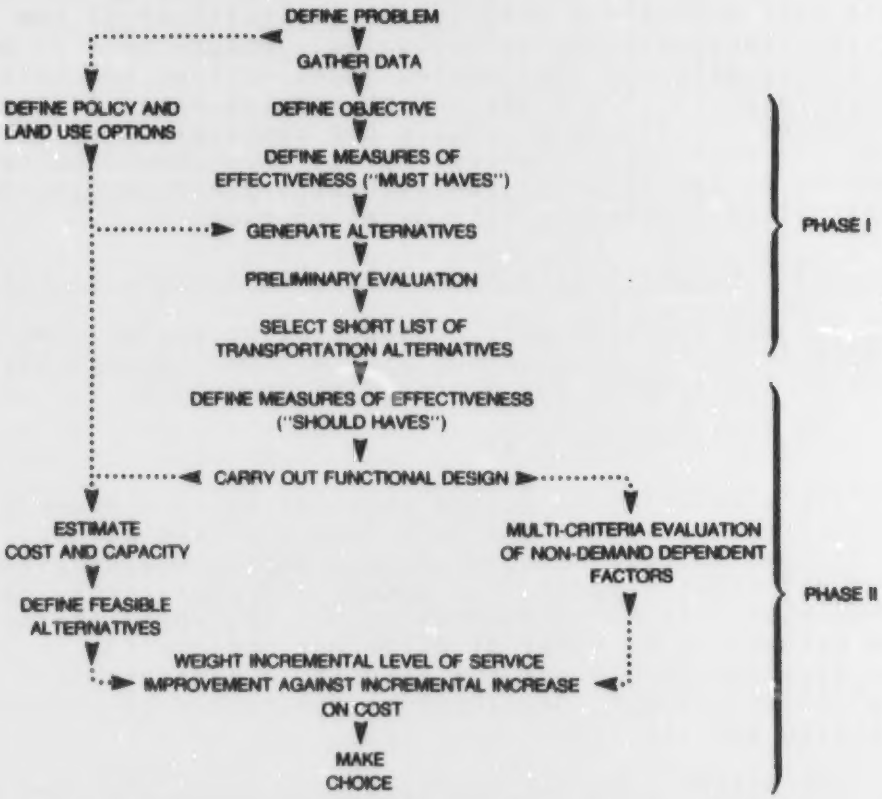

DEFINE PROBLEM
GATHER DATA
DEFINE POLICY AND LAND USE OPTIONS
DEFINE OBJECTIVE
DEFINE MEASURES OF EFFECTIVENESS ("MUST HAVES")
GENERATE ALTERNATIVES
PRELIMINARY EVALUATION
SELECT SHORT LIST OF TRANSPORTATION ALTERNATIVES
PHASE I
DEFINE MEASURES OF EFFECTIVENESS ("SHOULD HAVES")
CARRY OUT FUNCTIONAL DESIGN
ESTIMATE COST AND CAPACITY
MULTI-CRITERIA EVALUATION OF NON-DEMAND DEPENDENT FACTORS
DEFINE FEASIBLE ALTERNATIVES
PHASE II
WEIGHT INCREMENTAL LEVEL OF SERVICE IMPROVEMENT AGAINST INCREMENTAL INCREASE ON COST
MAKE CHOICE

Figure 1.2 Flow Diagram of Study Method

Planning for the third terminal was supposed to precede this study and provide the project team with guidelines about the location and form of major activity centres at the airport. This would have helped the team to narrow the main planning parameters, such as whether the third terminal would be built and, if so, what shape or size it would be and whether it would include a parking garage. Unfortunately, planning for the terminal did not stay far enough in the lead and, as a result, this analysis has not been able to recommend one set of solutions to the intra-airport transportation problem. Instead, the study has produced a range of solutions and an evaluation procedure.

In the summer of 1980, the Planning Branch of TIA conducted a comprehensive survey of the airport's users. This data was intended to be used to update the Groundside Travel Demand Model developed by the Ontario Region Planning staff of the Canadian Air Transportation Administration, Transport Canada. An updated demand model, it was felt, would more accurately predict the implications of the various transportation technologies. Unfortunately, both the survey data and the updated model arrived too late to be incorporated in this study, which remains based on the model calibrated on 1976 data. While the conclusions of this study are credible in general terms, they should be re-examined in the light of the 1980 survey and revised demand model before proceeding with detailed planning.

1.5 Compatibility With Other Transportation Plans

Any new intra-airport transportation system must contribute to the achievement of the other transportation goals of the airport and surrounding community.

1.5.1 TIA Master Plan

TIA's master plan brings together all the present plans for future improvement and development of the airport. It is intended to help management make day-to-day decisions about efficient airport development and operations. The master plan enables management to do this while at the same time preserving a number of different options for longer-term development. Since the airport is a mature facility in an advanced stage of development, the number of options for expansion are limited.

The master plan has been prepared using the "decision-point planning process" recommended in September 1979 by the joint federal/provincial report on Southern Ontario Multi-Modal Passenger Studies. That is, development of the airport will be undertaken on an incremental basis, so that long-term decisions can be deferred as long as possible.

As air traffic demand increases, so does the need to optimize the operation of TIA to allow maximum, efficient use of its facilities while maintaining safe, equitable levels of service. Systems are being put in place by TIA management to permit continual evaluation of the airport's performance in meeting demands for airspace, airside, terminal, and groundside facilities and service.

Air traffic forecasts prepared in 1979 indicate that, while traffic will not increase at the rate predicted earlier, it will still increase significantly. Therefore, five major developments are required at TIA during the 1980s and early 1990s:

- a third passenger terminal;
- expansion of air cargo operations;

- expansion and development of air carrier maintenance facilities;
- improvements to ground transportation facilities, primarily to serve the above developments;
- improvements to air traffic services and air navigational and airside facilities.

The master plan recommends that a final decision whether to proceed with a third passenger terminal be made as soon as the TDC analysis is completed. The analysis will determine the year the terminal must be opened and also specify the terminal's concept, size, and recommended phasing. The master plan also recommends that expansion of air cargo operations and expansion and development of air carrier maintenance facilities proceed as required. Associated ground transportation improvements will be required for these developments. Improvements to air traffic services and air navigational and airside facilities are also outlined in the master plan.

To achieve maximum use of airport lands, provision must be made for the distribution of people and goods between the various activity centres on the airport.

All of the alternative transportation technologies shortlisted in this study are consistent with the recommendations of the master plan. None of them restricts the development options for the airport. However, each technology's potential contribution to TIA's long-term development is vastly different.

1.5.2 Terminal 3 Plan

The exact location and layout of the third terminal and its final configuration (linear structure, piers, etc.) have not been established. A number of potential concepts for the terminal have been identified, however, and the terminal planning team is considering them. The implications of the uncertainty surrounding the third terminal have been given careful consideration in preparing the shortlist for this study.

1.5.3 Metro Transit Planning

The Toronto Transit Commission, Metro Toronto, and the Ontario Ministry of Transportation and Communication have agreed on four possible ways to extend Toronto's mass transit system. Three of these options pass very near TIA. These three are:

1. a line from Finch Avenue passing along Highway 401;

2. a line from Sheppard Avenue passing along Highway 401;

3. a line from Eglington Avenue.

The nearest point of passage is near the intersection of Highways 427 and 401, immediately south of the Wardair maintenance facility. Figure 1.3 shows three optional connections to an external rapid transit link.

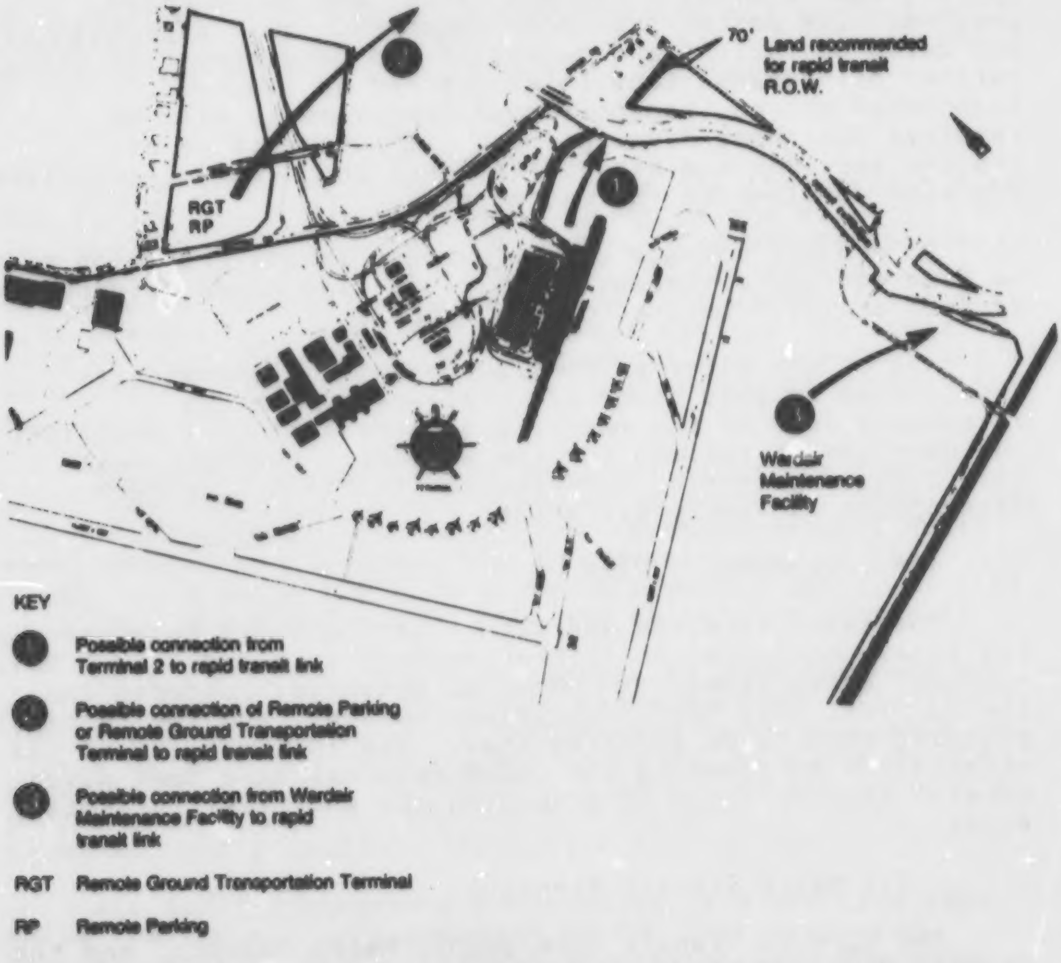

70'
Land recommended for rapid transit R.O.W.
RGT
RP
1
2
3
Wardair Maintenance Facility
KEY
1 Possible connection from Terminal 2 to rapid transit link
2 Possible connection of Remote Parking or Remote Ground Transportation Terminal to rapid transit link
3 Possible connection from Wardair Maintenance Facility to rapid transit link
RGT Remote Ground Transportation Terminal
RP Remote Parking

Figure 1.3 Rapid Transit Links to Toronto

If one of the three options is chosen, it would be desirable to link TIA's intra-airport transportation system with the city's mass transit system, to provide rapid and convenient access to the airport for employees and airport users.

This study has evaluated the ability of the shortlisted intra-airport transportation systems to effectively serve possible mass transit stations.

2. PROBLEM DEFINITIONS

TIA is Canada's busiest airport. It serves the nation's largest business and travel area. In 1981 TIA served 14 million passengers and handled 280,000 aircraft movements. This is expected to increase to 24 million passengers and 375,000 aircraft movements in 1991, at a growth rate of 5.7 per cent a year for passengers and 3.0 per cent a year for aircraft movements. Figure 2.1 is an aerial photograph of the airport and Figure 2.2 is a corresponding base map.

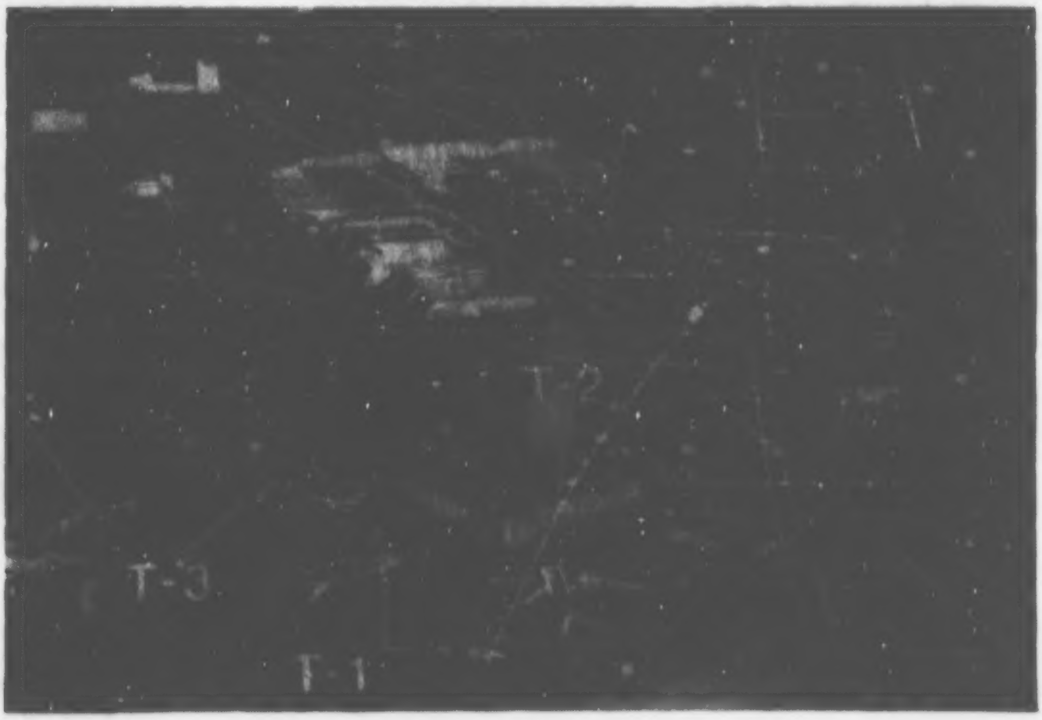


Figure 2.1 Aerial View of TIA

For the purpose of this study, the key areas are Terminal 1 (T1), shaped like an aeroquay, and Terminal 2 (T2), linear in configuration. They are connected by a pedestrian tunnel 250 metres long. The transportation hub area contains the bulk of the airport's internal road network servicing the two terminals and the air cargo area. The road network is tightly confined at the north-east corner of the airport property. Expansion of existing terminal capacity would further burden this area.

The present ground transportation system at TIA is becoming steadily more congested as air traffic increases. Yet it cannot grow because expansions to existing airport facilities have consumed available space. These factors have been recognized by the airport planning authorities and are well documented in earlier studies.[1] This study is aimed at researching and evaluating solutions to the following six problems.

2.1 Problem 1: Transferring Passengers

TIA's two passenger terminals are connected by a shuttle-bus service and an underground pedestrian tunnel with a moving ramp. A third terminal will be necessary to

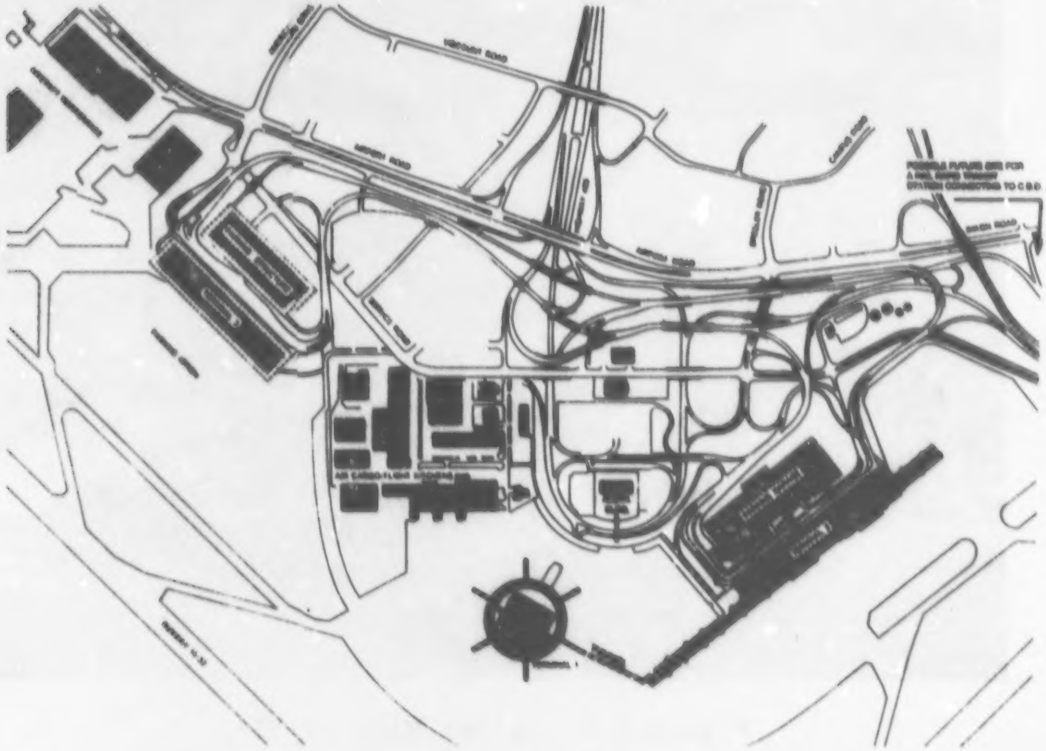


Figure 2.2 Toronto International Airport

handle expected growth in air traffic. The site earmarked for this new terminal (T3) is over a thousand metres to the west of the existing terminals, well beyond reasonable walking distance and separated from the existing terminals by a cargo and aircraft maintenance area. A serious intra-airport transportation problem will occur if the airlines serving TIA are assigned to three terminals rather than two and passengers must make connections with airlines located in other terminals. Of course, much can be done to minimize the need for inter-terminal transfers by a judicious allocation of the airlines to each terminal, but unfortunately inter-terminal transfer is not the only factor in deciding such allocations. When other important factors such as peaking are considered, allocating the airlines on the basis of minimizing inter-terminal transfers could be very wasteful, especially of the large capital resource represented by the terminal itself.

---

[1] Transport Canada. Malton Toronto International Airport Contingency Plan Study. Volumes 1 and 2. Report prepared by Toronto-Area Airports Project, 1978. Transport Canada. Southern Ontario/Montreal Air Transportation Study (SOMATS). Prepared for Canadian Air Transportation Administration, 1980.

The possibility also exists that more efficient use could be made of the existing airport gate positions by pooling them and, in effect, operating all three terminals (or even the existing two terminals) as one large terminal. Passengers might be processed in one terminal, but transferred to another for departure. Similarly, arriving passengers might deplane at an available gate at any one terminal and be transferred to their airline home terminal, rather than have airplanes and passengers waiting while gates stand empty. Although most airlines would not welcome such an arrangement, it certainly makes economic sense when one considers that the need for this type of extreme operation would only occur during a few weeks of the summer peak period. It is difficult to justify the cost of providing additional gates to handle such extreme peaking when it is known that gates will stand empty at adjacent terminals. To make this pooled gate concept workable, a high-quality (i.e., rapid and frequent) inter-terminal transportation system would be required; ideally, it would transfer people between terminals as easily as elevators transfer people between floors.

2.2 Problem 2: Parking

TIA has a serious shortage of parking space for automobiles, particularly at T1. The shortage at T1 is expected to continue, and even grow worse under certain scenarios, despite the construction of a parking garage at T3 and the transfer of certain airlines from T1 to T3. A number of locations for supplementary parking have been identified but in most cases these are beyond reasonable walking distances from T1 (Figure 2.3).

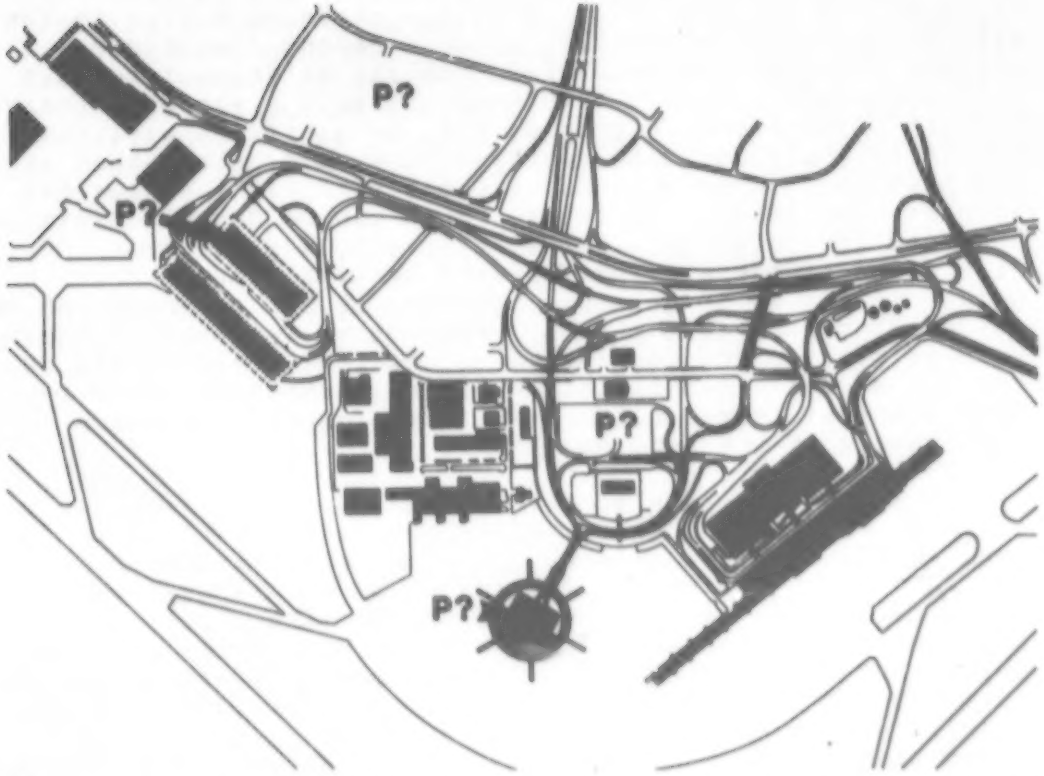


Figure 2.3 Potential Parking Sites and Access Road Congestion

To adequately integrate new car-parks into the airport in a way which will ensure that airlines operating from T1 have the same parking facilities as airlines operating out of the other terminals, a high quality, efficient transportation link is required between the car-park and the terminals.

There is at present a surplus of parking and curb space at T2. However, this surplus cannot be used to help solve the shortage at T1 because the inter-terminal transportation systems are poor. This inadequacy is experienced by those air travellers who park at, and depart from, one terminal, but return later in the day to the other terminal and must make their way back to their cars. High-quality transportation between the terminals would considerably improve service for these travellers.

2.3 Problem 3: Traffic Congestion

T1 was designed in the early 1960s as an aeroquay. The airplane apron and gates surround the circular terminal building, and auto and bus traffic reach the terminal's curbs and central parking garage via a road tunnel under the apron. The design of this tunnel is quite constrained; the designers did not foresee the traffic demands that would be placed upon it. During peak periods, traffic jams in the tunnel cause long delays for departing passengers arriving by auto or bus. Figure 2.3 shows the location of these highly congested roads into and out of T1. One solution to this traffic problem would be to channel traffic into a remote car-park before it reaches the tunnel, and then transport the passengers and others from this remote location to T1. Only a high-quality transportation system could be expected to attract traffic from direct access to T1's curb and car-park, and so help to ease traffic congestion.

2.4 Problem 4: Bus Service

TIA serves as a hub airport for much of southern Ontario. As such, it attracts buses not only from downtown Toronto but also from surrounding communities. These buses serve each terminal separately, first dropping off passengers at departure levels then circling to load passengers at the arrivals level, as shown in Figure 2.4. This multi-stop operation, coupled with time lost negotiating the airport's road system, imposes additional delays on passengers and seriously impairs the efficiency of the buses, which waste a good deal of time at the airport which could be better spent transporting people to and from it. Moreover, the buses themselves constitute a major source of congestion at T1, where poor road design restricts their manoeuvrability. This problem will be aggravated if and when the buses are forced to serve three terminals. One solution would be to provide a one-stop central bus station at the airport. To make this practicable, however, a high-quality ground transportation system would be necessary to link the terminals and the central bus station. This scheme would also free valuable curb space for other airport users and simplify the decision process for bus users, who would be conveyed to a bus terminal rather than be left, as they are now, to find their own way at curbside.

2.5 Problem 5: Rapid Transit Service

The Ontario government plans to extend Toronto's rapid transit system to pass on or near the airport. To make the best use of this development (particularly for transporting employees and to persuade people to use rapid transit rather than their cars), a high-quality transportation system would be necessary to link activity centres and the rapid transit station (Figure 2.4).

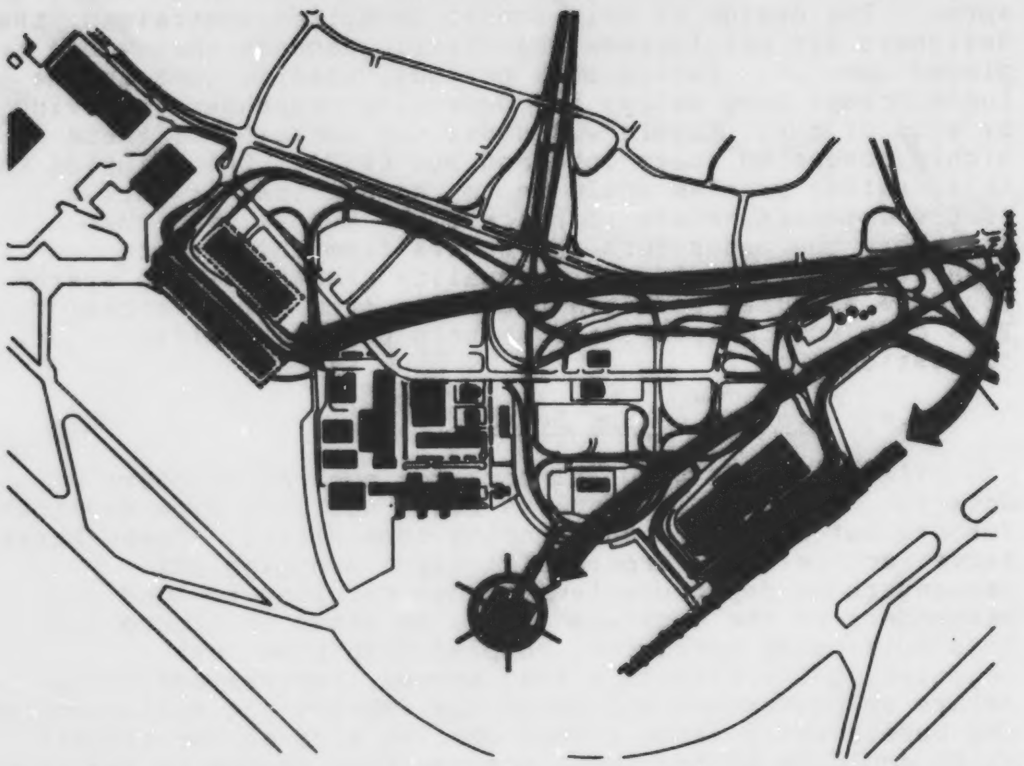


Figure 2.4 Bus Routes and Future Transit Station Connection

2.6 Problem 6: Hotel Service

Construction of a hotel on the airport is being considered to serve the needs of airport users. Passengers now have the option of using hotel courtesy vans to reach a number of nearby hotels. To make an airport hotel competitive, some form of high-quality transportation system would be necessary to link the hotel to the passenger terminals and other activity centres (Figure 2.5).

In conclusion, an airport transportation system will be needed to link the major activity centres at the airport. The question this study is directed to answer is: what type of system will best meet the future needs of the airport?

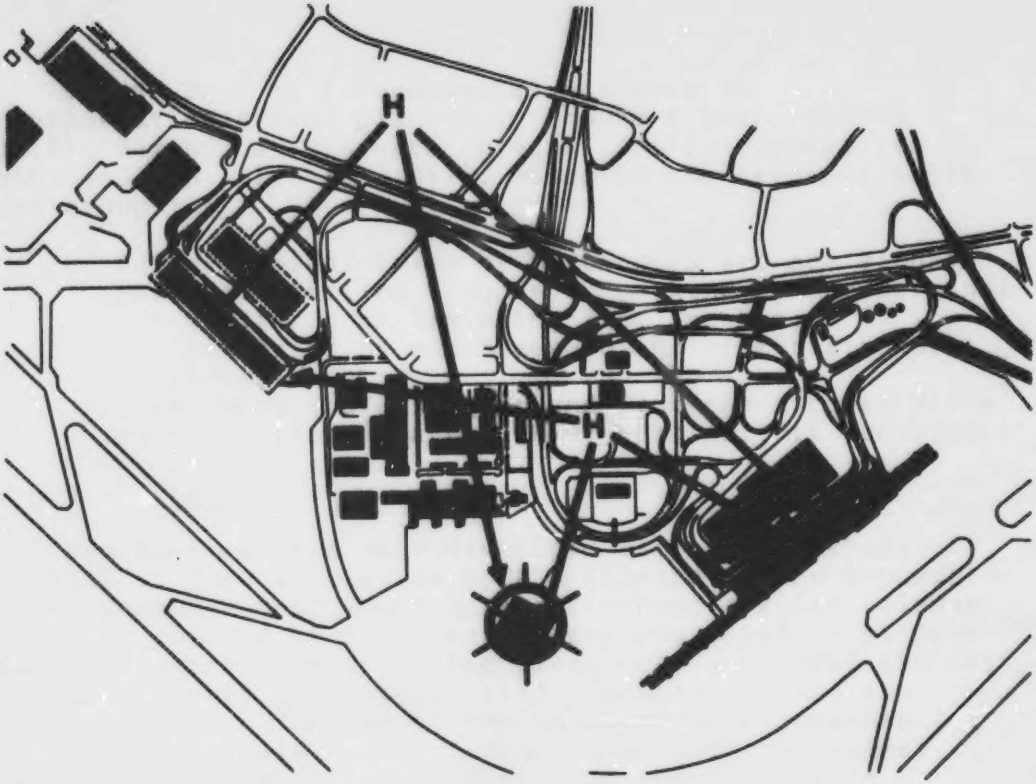


Figure 2.5 Service to Airport Hotels

[illegible]

[illegible]

[illegible]

3. DEMAND ANALYSIS

Demand data is a fundamental variable for transportation system planning. Ground transportation traffic demands at TIA were forecast for five years (to 1986) and ten years (to 1991), based on the needs of three user groups:

- inter-terminal trips by passengers who are either making connecting flights or parking at one terminal but enplaning or deplaning from another;
- on-site trips by employees to and from their work stations;
- passengers travelling to [illegible] from the airport via a central ground transit (b[illegible] terminal, if provided.

3.1 Method

Demand forecasts were developed using two methods: (1) traffic flow simulation models (including the Groundside Travel Demand Model) which forecast ground traffic volumes at TIA to the end of the planning periods based on airport users' air travel demand, trip frequency, and modal choice; and (2) a survey of airport users conducted during the summer of 1980. The use of two independent approaches for the demand analysis -- one factoring up from the summer survey, the other factoring down from annual data -- delineates the boundary of the forecast result and provides a measure of the probable error in these forecasts.

3.2 Inter-terminal Trips

Connecting passenger demands are based on 1979 adjusted data, which depict annual passenger volumes distributed to, and acquired from, airlines operating connecting flight pairs at TIA. Expanding these connections using flight sector growth rates to 1986 and 1991, and distributing the resulting passenger trips among the three terminals on the basis of the eight airline assignment scenarios envisaged after the addition of T3, produces the range of inter-terminal connections shown in Table 3.1.

Table 3.1 Estimated Inter-terminal Flow of Connecting Passengers

	1986		1991	
	Low	High	Low	High
Peak-hour Connecting Passengers	350	470	515	700

Inter-terminal trips by originating-terminating (O-T) passengers occur whenever trip itineraries result in passengers returning to TIA by way of a terminal different from that of their departure. A secondary factor affecting forecasting of their needs is parking constraints at T1 and T2, which will require passengers to park remotely. In both cases, inter-terminal traffic demands arise from passengers completing their airport trips. O-T demands are based on application of a fixed ratio of such inter-terminal trips to daily enplaned-deplaned passengers at each terminal for each airline.

Inter-terminal demands generated by insufficient parking at T1 and T2 are considered only when a remote car-park is an explicit development option. Parking demands estimated by the Groundside Travel Demand Model are adjusted to account for parkers attracted to off-site and competing on-site car-parks. The resulting shortage is converted into passenger trips using an occupancy rate of 1.5 passengers per vehicle. Table 3.2 shows the range of inter-terminal traffic demands by O-T passengers.

Table 3.2 Estimated Inter-terminal Flow of O-T Passengers (Itinerary Based and Remote Parkers)

	1986			1991		
	Low	Mean	High	Low	Mean	High
Peak-hour O-T Passengers (Itinerary Based)	-	320	-	-	400	-
Peak-hour O-T Passengers (Remote Parkers)	345	1,710*	2,350	2,870	3,830*	

Note: * Parking shortage at T1 during peak hour, diverting users to remote car-park.

3.3 On-site Employee Trips

It is estimated that the average daily employment at TIA will be about 6,100 employees by 1991, of which 4,250 will be required to park at a distance from their work stations. Wherever this car-park is situated, it is forecast that 25 per cent of employees will use the on-site transportation system to move from the car-park to their work-stations during the peak afternoon period.

Employment distribution patterns are still uncertain at TIA. However, for comparative purposes, the demands shown in Table 3.3 have been assumed. These are based on an employment growth rate of 3 per cent a year.

Table 3.3 Estimated Employee Trips: 1986, 1991

	Peak Hour Outbound Employee Trips						
	T1	T2	T3	Cargo	Admin.	Maint.	Peak-hour Employee Trips Total
1986	135	170	55	75	315	120	870
1991	160	210	75	95	380	140	1,060

3.4 Ground Transit Terminal and Hotel Trips

A central transit terminal and a hotel, either on or off the airport site, will concentrate local and regional transit passengers at one location. The Groundside Travel Demand Model is used to calculate transit demands at each of the three terminals. Also taken into account are the transit-using propensities of the passengers associated with each of the airline assignments. The estimated demands by these transferring passengers are shown in Table 3.4.

Table 3.4 Estimated Transit-Transferring Trips: 1986, 1991

	1986			1991		
	Low	Mean	High	Low	Mean	High
Peak-hour Transit-Transferring Passengers	1,000	1,050	1,080	1,280	1,300	1,360
Hotel	0	225	450	0	225	450

3.5 Total Ground Transportation Demand

The peak hour for airport activity has always been in the late afternoon. Demand for intra-airport transportation peaks at the same time. Table 3.5 shows the estimated range of peak-hour demands in 1986 and 1991. Decisions about the peak-hour capacity of the system must take into account directional volumes as well as maximum route link volumes. These are discussed in Technical Working Paper Number 8. A summary of this working paper is provided in Figures 3.1 and 3.2, which present the minimum and maximum peak-hour demands in 1991 for TIA's intra-airport transportation system, by route link volumes.

Table 3.5 Estimated Total Demand

	1986		1991	
	Low	High	Low	High
Inter-terminal trips				
- Connecting	350	470	515	700
- Originating-Terminating	320	325	400	400
- Remote Parkers	0	1,710	2,350	3,830
Employees	870	870	1,060	1,060
Transit-Transferring	1,000	1,080	1,310	1,360
Hotel	0	450	0	450
Peak-hour Demands	2,540	4,905	5,635	7,800

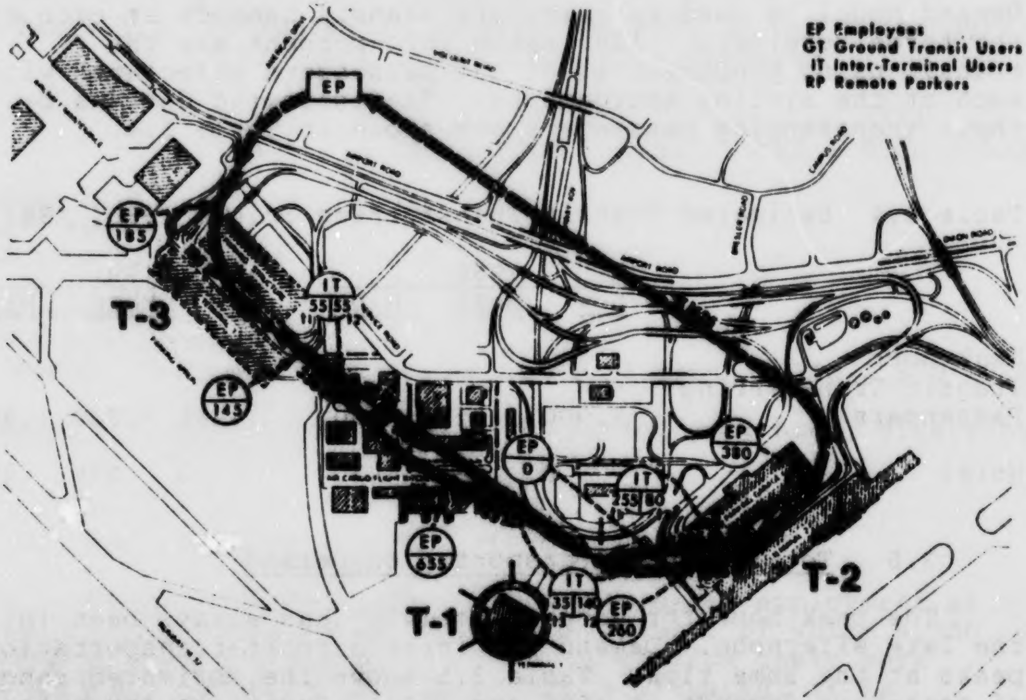
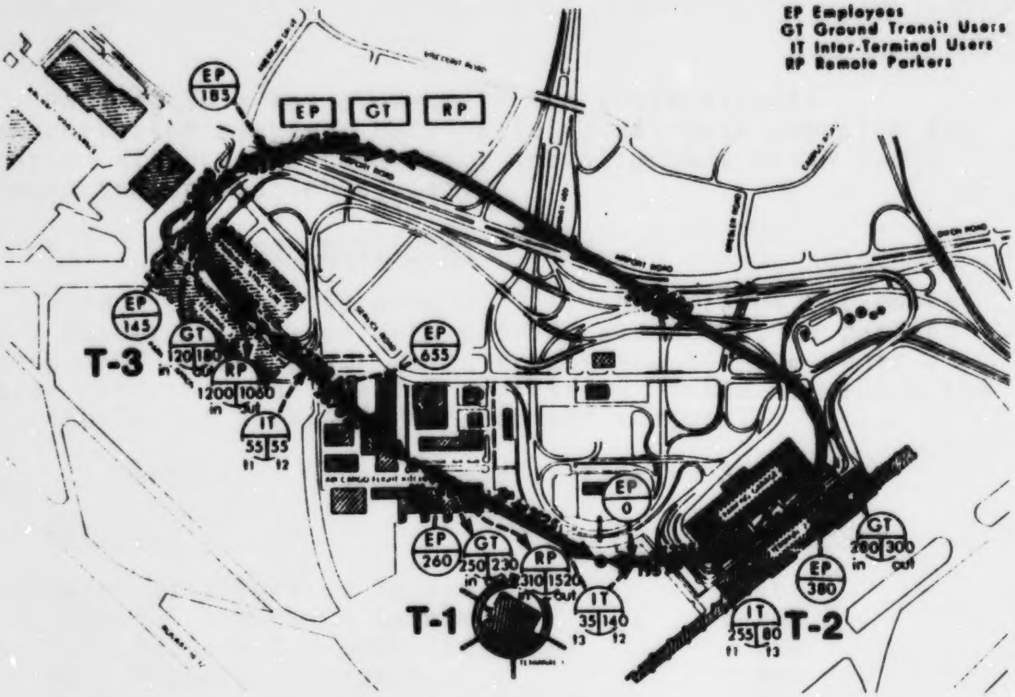

EP Employees
GT Ground Transit Users
IT Inter-Terminal Users
RP Remote Parkers
EP
EP 185
T-3
IT 55 55
11 12
EP 145
EP 0
EP 380
IT 255 80
EP 635
IT 35 140
13 12
EP 260
T-1
T-2

Figure 3.1 Peak-hour Demand in 1991: Minimum Case



EP Employees
GT Ground Transit Users
IT Inter-Terminal Users
RP Remote Parkers
EP 185
EP
GT
RP
AIRPORT ROAD
EP 145
GT 120 180 in out
T-3
RP 1200 1060 in out
IT 55 55 t1 t2
EP 655
EP 0
EP 260
GT 250 230 in out
RP 310 1520 in out
IT 35 140 t3 t2
T-1
GT 200 300 in out
EP 380
IT 255 80 t1 t3
T-2

Figure 3.2 Peak-hour Demand in 1991: Maximum Case

4. PARKING OPTIONS

Parking is a key element in the intra-airport transportation system. Rationalizing car-park capacity and location affects the technology and alignment of an intra-airport transportation system.

4.1 Existing Facilities

Within the central area of TIA, three large car-parks and a number of smaller ones provide almost 13,000 parking spaces. Of these, about 7,750 spaces are for the general public, and the rest are for employees. Table 4.1 shows the distribution of parking spaces at the airport.

Table 4.1 Distribution of Parking Spaces

Facility	Number of Spaces
Terminal 1 Parking Garage	2,481
Terminal 2 Parking Garage	5,267
Reduced Rate Car-park (Surface)	870
Main Employee Car-park	2,943
Parking at Administration Building	500
Miscellaneous Employee Parking	±700

The three large public car-parks (T1, T2, and reduced rate) are managed and operated by a private firm under contract to Transport Canada. Based on the 1982 contract price, the unit operating cost for public parking is about $200 per parking space per year. Maintenance carried out by Transport Canada is estimated to cost $25 per parking space per year. The T1 garage generates a revenue of $1,250 per space per year; the T2 garage generates $900; and the reduced rate car-park generates $570. Parking is one of the main sources of revenue at TIA.

Private operators along Airport/Dixon Road provide an additional 2,150 parking spaces off-site. The majority of the operators charge $3.00 to $3.50 a day to park. This price includes free transportation to and from the airport by courtesy vehicles which use the passenger terminal curbs for delivery and pickup. In addition, some nearby hotels provide limited free parking to air travellers staying at the hotels.

4.2 Future Parking Demands

The demand for public parking at T3 in 1991 is estimated at between 1,710 and 3,260 spaces, depending on the air traffic allocated to that terminal. Employee requirements must also be taken into account because of the possible impact of the T3 ground transportation facilities on the existing main employee car-park, and because land is scarce for expanding employee parking. Based on a moderate employment growth of 3 per cent per year, an estimated 1,600 spaces of additional employee parking will be needed in 1991.

4.3 Parking Options

T3 is assumed to be a linear terminal for the purpose of this analysis, though its final configuration could be different. Two basic options for public parking at T3 were identified. Option A provides a parking garage, while Option B provides a surface car-park. Sub-options were identified to take into account employee parking requirements:

Option A

1 - public parking garage for T3 with employee parking at existing location;

2 - public parking garage for T3 with employee parking relocated at remote site north of Airport Road;

3 - public parking garage for T3 with employee parking in a parking garage located north of the administration building at a site now occupied by the reduced rate car-park.

Option B

1 - short-term public parking at a surface car-park adjacent to T3, long-term public parking at a remote site north of Airport Road, and employee parking retained at existing location;

2 - short-term public parking at a surface car-park adjacent to T3, long-term public parking at existing employee car-park, and employee parking relocated at remote site north of Airport Road;

3 - a variation in the layout of Option B2.

The combination of surface public parking for T3 with an employee parking garage was not deemed feasible and was not included in this study.

Because of events following the completion of Technical Working Paper Number 9, parking Options A2, A3, and B3 are considered the most feasible. They are described in more detail below.

4.3.1 Option A2 (Figure 4.1)

A parking garage about 270 metres by 100 metres would provide about 850 spaces per level. Three to five levels would be required, depending on the airline allocation for T3. The capital costs, including access and egress ramps and computerized revenue control equipment, would range from $19.9 million to $32.8 million (1980 dollars).

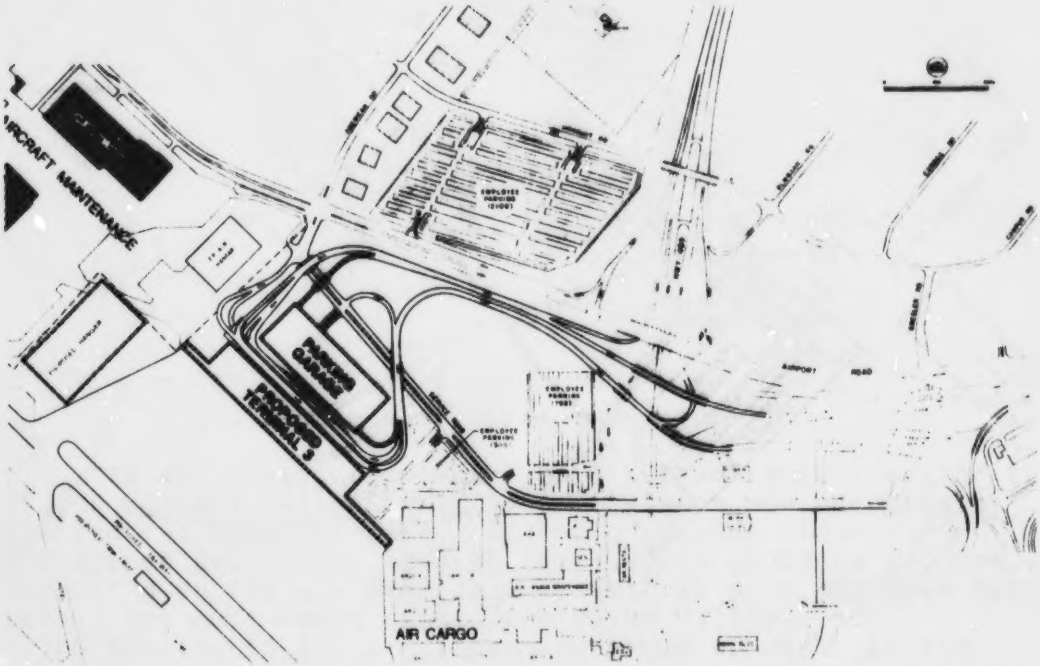


Figure 4.1 Parking Option A2

Most of the required 2,900 parking spaces for employees would be at the remote site. The construction of this car-park, together with the new employee car-park adjacent to T3 and the retention of part of the existing main employee car-park, is estimated to cost $3.8 million.

Because of the difficulty in providing direct access to the remote car-park from the internal road system at TIA, access would be limited to three entrances, one on Airport Road and two on Viscount Road. As a consequence, traffic exiting from the car-park onto Viscount Road would experience significant delays because of the relatively high traffic volumes using this collector road during the afternoon peak periods.

A shuttle bus would be needed to link the remote car-park to the airport proper. If local traffic delays the service or if a direct link to the airport is desired, a connector road could be constructed with a grade separation at Airport Road (Figure 4.2). The road is estimated to cost $2.2 million.

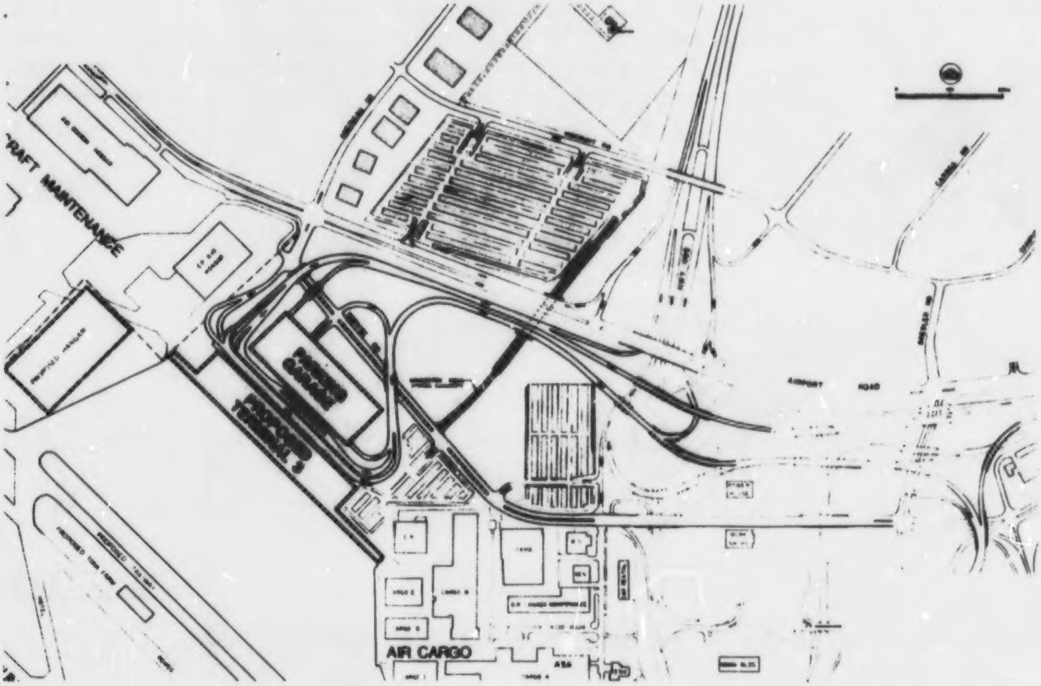


Figure 4.2 Connector Road to Remote Car-park

Other types of transit systems, such as an automated guideway transit system, could be routed to serve the remote car-park. Providing a station within the car-park would cost about $0.3 million, excluding the cost of operating the guideway system.

4.3.2 Option A3 (Figure 4.3)

Two parking garages would be constructed, one for the public and the other for employees. The public garage is identical to the one in Option A2, described above, and the same considerations apply here.

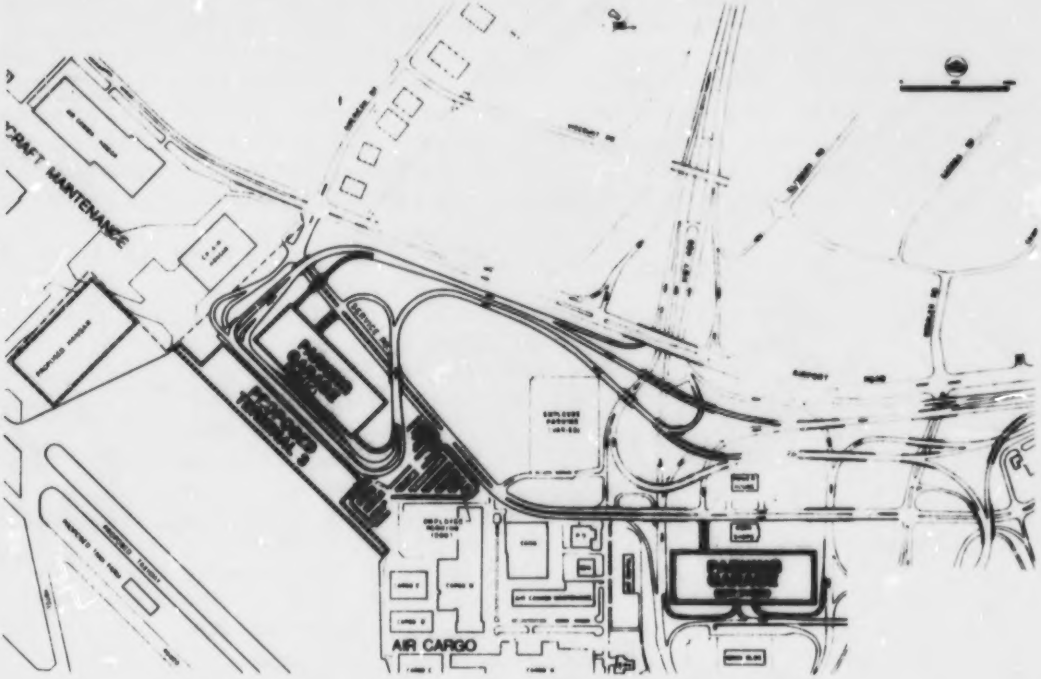


Figure 4.3 Parking Option A3

The employee garage would be situated immediately north of the administration building on the site now occupied by the reduced rate car-park. It would provide about 870 spaces per level. Two to four levels would be required, depending on the use made of the residual main employee car-park. The cost would range from $11.9 million, for 1,700 spaces, to $23.8 million for 3,500 spaces. Access would be relatively easy, by the Ring Road as well as from the Service Road. Depending on the size of the garage, however, exiting could be a problem, due to traffic on the outbound Ring Road.

4.3.3 Option B2 (Figure 4.4)

All public parking would be provided within the airport's operational area, but it would remain separated into short-term and long-term parking, as in Option B1. The short-term car-park would be the same as in Option B1. It would provide a minimum of 900 spaces on a surface lot in front of T3. The long-term car-park would replace the existing main employee car-park. Together, these two car-parks could provide a total of 3,400 spaces at a cost of about $2.3 million.

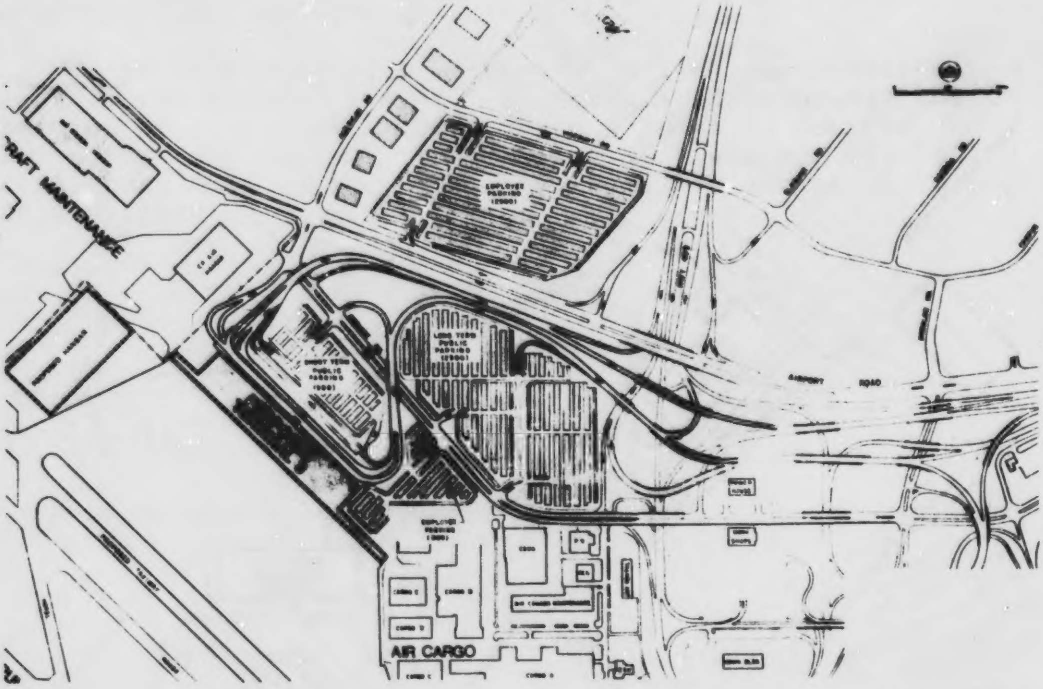

RAFT MAINTENANCE
EMPLOYEE PARKING (2000)
LONG TERM PUBLIC PARKING (2500)
SHORT TERM PUBLIC PARKING (900)
AIRPORT ROAD
AIR CARGO

Figure 4.4 Parking Option B2

Although access to and from the short-term car-park would be identical to Option B1, access to and from the long-term car-park would be substantially improved because it would be closer to T3. Nevertheless, as was the case in Option B1, the parking arrangement would have major drawbacks. These include its operation in terms of function of the short-term car-park, roadway signing, and establishment of an equitable rate structure. Because the long-term car-park would be closer to T3, users could walk from their cars to the terminal. However, average walking distances exceed accepted norms, and so some form of bus service would be necessary.

Employee parking would be identical to Option A2, described above.

4.4 Conclusions

The primary objective of this analysis is to provide information about six sub-options for parking at T3, rather than try to determine the best one.

All of the sub-options are feasible physically; however, they have widely varying operational characteristics, capital costs, and operation and maintenance costs. Table 4.2 highlights the six sub-options and their characteristics. Conclusions about the most cost-effective option should not be drawn from the data presented in Table 4.2 since all of the key elements are not included. For example, transit implications covered in other tasks of this study could affect the cost/benefit equation.

Note that:

(1) All costs are in 1980 dollars.

(2) Public parking for A1, A2, and A3, as well as part of the employee parking for A3, is in the form of a parking garage. All other parking is surface car-parks.

(3) In some cases, ranges of costs are given when the parking supply can be varied, for example, in the number of levels in a garage.

Table 4.2 Summary of Parking Sub-options and Their Characteristics

Parking Option		Parking Capacity (no. of spaces)	Capital Cost ($ millions)	Annual Costs ($)		Accessibility & Traffic Operation	Advantages	Disadvantages
				Operating	Maintenance			
A1	Public Parking	2,350 to 4,050	19.9 to 32.8	400,000 to 690,000	60,000 to 100,000	• very good	• high level of service • reduces land consumption for parking • establishment of fair parking rates	• high capital cost
	Employee Parking	4,250 (2,600 + 500 + 1,150)	2.2	NIL	106,000	• good	• retains bulk of existing parking • remote site to be developed as req'd	• requires transit for remote site • reduces flexibility for cargo expansion
A2	Public Parking	2,350 to 4,050	19.9 to 32.8	400,000 to 690,000	60,000 to 100,000	• very good	• high level of service • reduces land consumption for parking • establishment of fair parking rates	• high capital cost
	Employee Parking	4,250 (2,900 + 500 + 850)	3.8	NIL	106,000	• problematic	• provides flexibility for cargo expansion	• remote parking requires transit service (and possibly road connection to airport proper) • delays for traffic exiting from remote lot
A3	Public Parking	2,350 to 4,050	19.9 to 32.8	400,000 to 690,000	60,000 to 100,000	• very good	• high level of service • reduces land consumption for parking • establishment of fair parking rates	• high capital cost
	Employee Parking	4,250 of which 1,700 to 3,500 would be structural parking	11.9 - 23.8	NIL	106,000	• good	• all parking within airport proper • some employee will have very convenient parking	• high capital cost • reduced rate lot is displaced
B1	Public Parking	3,700 (900 + 2,800)	4.7	710,000	93,000	• problematic	• low capital cost	• low level of service • consumes large amounts of land & precludes cargo expansion • transit service required for remote lot (and possibly road connection to airport proper)
	Employee Parking	4,250 (2,600 + 500 + 1,150)	2.2	NIL	106,000	• good	• retains bulk of existing parking • remote site to be developed as req'd	• requires transit for remote site • reduces flexibility for cargo expansion
B2	Public Parking	3,400 (900 + 2,500)	2.3	650,000	86,000	• problematic	• low capital cost	• low level of service • consumes large amounts of land and precludes cargo expansion
	Employee Parking	4,250 (2,900 + 500 + 850)	3.8	NIL	106,000	• problematic	• provides flexibility for cargo expansion	• remote parking requires transit service (and possibly road connection to airport proper) • delays for traffic exiting from remote lot
B3	Public Parking	2,900 (1,200 + 1,700)	3.6	540,000	73,000	• some problems, but better than B1 and B2	• low capital cost providing intermediate level of service • logical layout of facilities	• consumes large amounts of land and precludes cargo expansion • egress from long term carpark problematic
	Employee Parking	4,250 (2,900 + 500 + 850)	3.8	NIL	106,000	• problematic	• provides flexibility for cargo expansion	• remote parking requires transit service (and possibly road connection to airport proper) • delays for traffic exiting from remote lot

5. TRANSPORTATION SYSTEM ALTERNATIVES

The project team looked at all available transportation technologies to identify those which would be acceptable for an intra-airport system. They reviewed the literature, visited sites, and then developed planning parameters, keeping in mind such constraints as the alignment and system layouts possible at TIA. These parameters were used to develop criteria for acceptance of a technology. Detailed evaluations were then conducted and a shortlist of technologies drawn up.

5.1 Literature Review and Site Visits

The team reviewed the technical literature data bases and over 400 reports and studies from Toronto Area Airport Projects. Of this literature, some 150 pieces relevant to TIA were compiled and categorized.

This information was used to prepare Interim Report Number 1: Strategic Options and Evaluation Criteria, and Technical Working Papers Numbers 3, 5, and 7. It was also used to decide which sites the project team would visit.

The purpose of the site visits was to obtain a candid assessment of the performance of a wide range of transportation systems currently in use at North American airports, from the people actually operating them. Background information was also gathered on:

- the planning and decision process leading up to the installation of the system;
- the cost of constructing and operating the system, compared with original estimates;
- public response to, and acceptance of, the system, particularly problems with opposition from special interest groups (such as the taxi industry).
- maintenance and other operating problems, particularly those of system reliability and labour relations;
- suggestions on how the system's operators would change their system layouts or operations if they were starting all over again.

The lessons learned from people who had actually operated the sophisticated transportation systems were considered one of the most important inputs in evaluating the technology.

The team visited the following eleven sites:

- Toronto Zoo, Bendix System
- Kansas City International Airport, (Red) Shuttle-bus System
- J. F. K. International Airport, New York, Shuttle-bus System
- Tampa International Airport, Florida, Westinghouse System
- Miami International Airport, Florida, Westinghouse System
- Orlando International Airport, Florida, Westinghouse System
- Atlanta International Airport, Georgia, Westinghouse System
- Disney World, Orlando Florida, WEDway System
- Houston International Airport, Texas, WEDway System
- Dallas-Fort Worth International Airport, Texas, Airtrans System
- UTDC Kingston Test Track, Ontario, Intermediate Capacity Transit System

Photographs of nine of the systems are shown on the next five pages, Figures 5.1 to 5.9.

Figure 5.1 The Bendix "Dashaveyor" System at Toronto Zoo

Figure 5.2 The Kansas City International Airport "Red Bus"

Figure 5.3 The J. F. K. International Airport Shuttle Bus

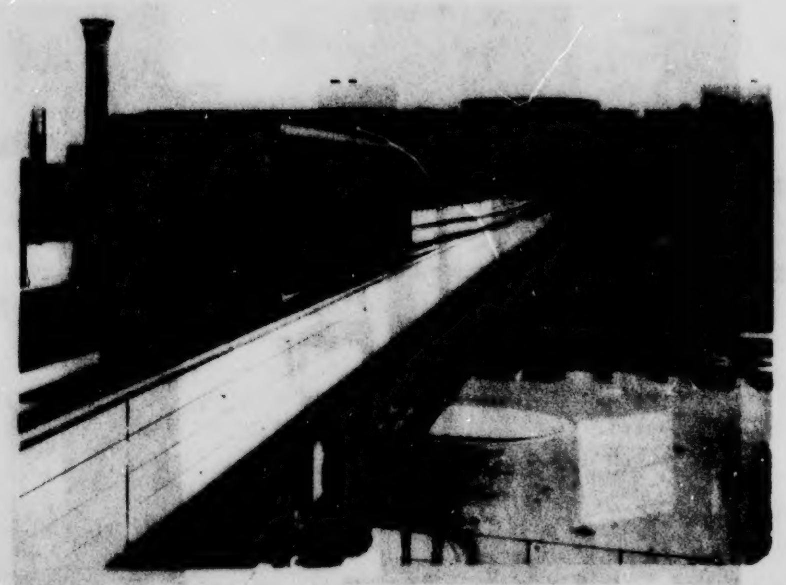


Figure 5.4 The Westinghouse System at Tampa International Airport

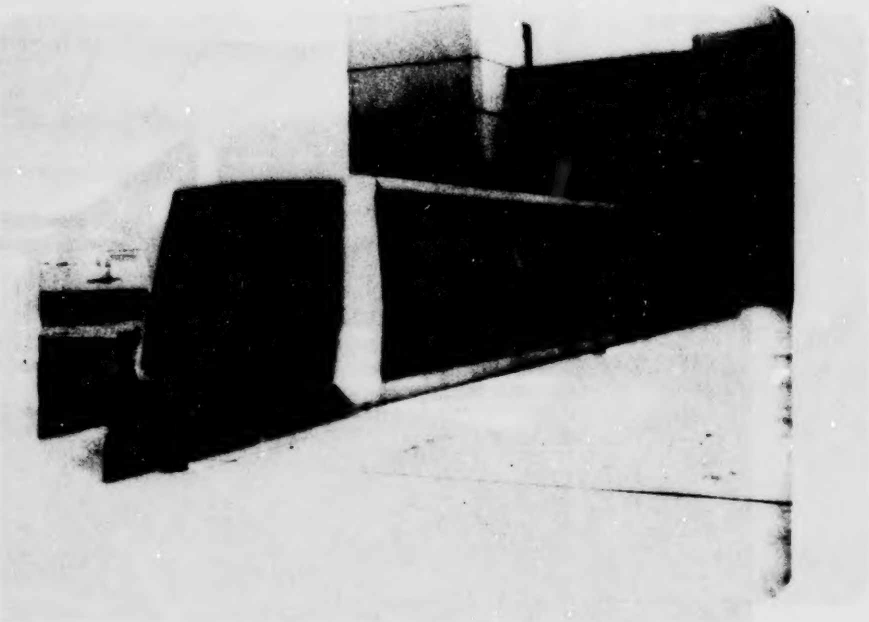


Figure 5.5 The Westinghouse System at Miami International Airport

Figure 5.6 The Westinghouse System at Atlanta International Airport

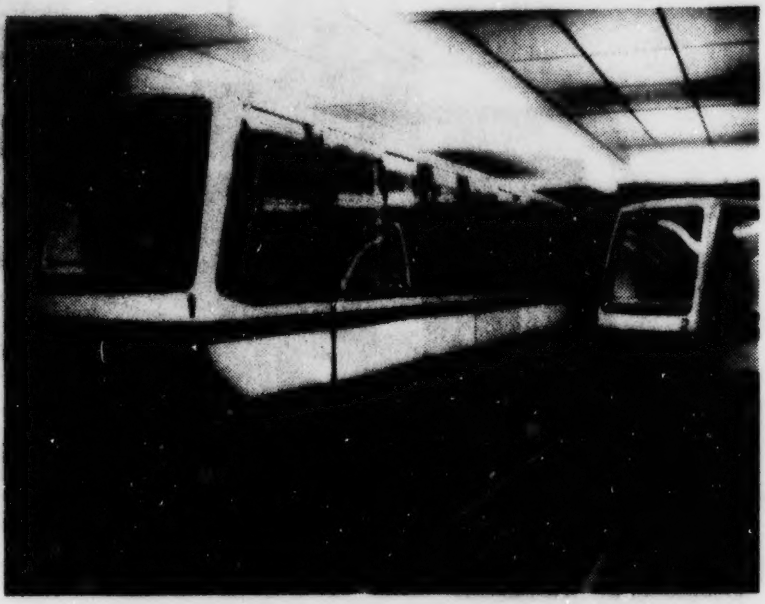


Figure 5.7 WEDway Vehicles at Houston International Airport

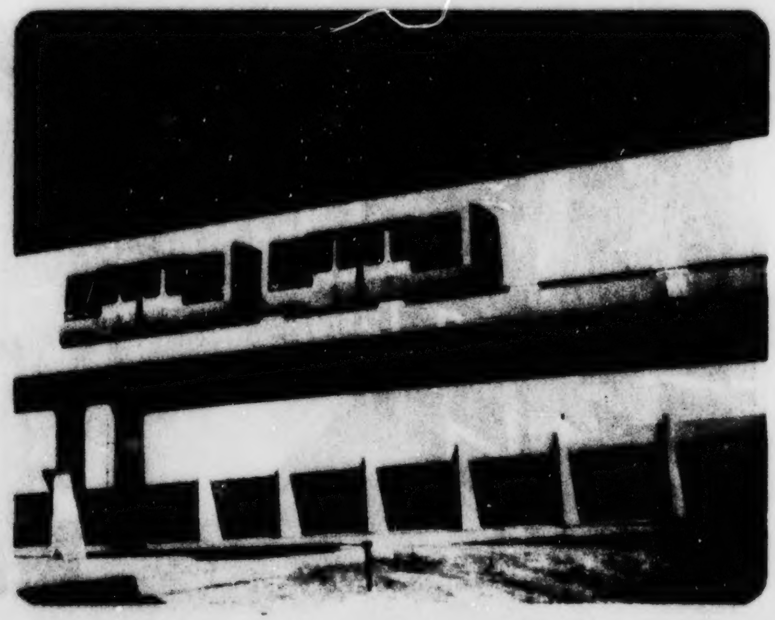


Figure 5.8 The Airtrans System at Dallas-Fort Worth International Airport

Figure 5.9 The Intermediate Capacity Transit System at Kingston

Full reports of the site visits are in Technical Working Paper Number 6.

5.2 Planning Parameters

The lessons learned from the literature review and site visits were translated into four sets of planning parameters for this study: system selection parameters, user acceptance parameters, cost parameters, and design and operation parameters.

5.2.1 System Selection Parameters

Proven revenue operation

- Caution should be exercised if a supplier proposes to use TIA as a test bed to prove a new system or new system component. Ideally, at least one year's proven service elsewhere should be insisted upon.

Supplier continuity

- Two system suppliers (Rohr and Bendix) have gone out of the people-mover business since their systems were installed. The mortality rate among suppliers of automated guideway transit systems is high. Efforts should be made to identify systems by suppliers who are not likely to disappear from the market-place and leave TIA with their technology.

Quality and reliability of product

- Selection should not be based solely on the lowest bid price. Suppliers should agree to accept stiff financial penalties if their system does not prove reliable.

Procurement procedure

- A two-stage procedure for procurement is desirable: first, a general request for proposals; second, a more detailed lump-sum bid for implementation and operation/maintenance for a fixed period of time.

Flexibility and planning for the future

- In redeveloping Newark Airport, the New York Port Authority constructed automatic guideway transit stations in each of the three terminals, despite the fact that there are no firm plans to connect these stations with a guideway system. The Port Authority was planning for the future and took advantage of the low cost of providing the stations during initial construction. The lessons of this kind of foresight should not be lost in planning for T3.

Image versus economics

- Automated guideway transit systems seem to appeal to image-conscious airport authorities, such as Houston, and especially those building new terminals. The New York Port Authority, with a tight budget, evaluated the available guideway systems on the basis of practicality and economics, and chose a bus system instead.

Incremental improvements and teething problems

- Buyers should be prepared for a breaking-in period in a new technology system. The two proven systems (WEDway and Westinghouse) have evolved step by step: each new design has incorporated improvements incrementally, until high performance is now attained. Systems in which everything is new have most frequently proven Murphy's Law: if something can go wrong, it will.

System simplicity and spare parts supply

- The simpler the system, the fewer the problems. The simplicity of the WEDway system is to be prized. The availability of spare parts locally should be identified early in the proposal stage.

Winter operations

- Snow and ice pose major problems at TIA. Rubber-tired guideway systems have had mixed success in winter. The Airtrans system fails under winter conditions, while the Bendix system at Toronto Zoo appears to cope well. Short headway operations do not appear possible in winter with these systems, and such performance may not be required at TIA. UTDC's linear induction propulsion system appears to provide an answer to the winter traction problems because thrust is not transmitted through the wheels.

Consultation with airlines

- Airlines should be included in the decision-making process.

Rapid transit interface

- Atlanta constructed a rapid transit station in its new airport despite the fact that the subway will not be extended to the airport for five to ten years. This kind of foresight will pay great financial dividends in the future. This lesson should not be lost in planning T3, even if a regional rapid transit system is not in sight.

Realistic specifications

- When suppliers are invited to submit detailed proposals, the specifications must be clear and comprehensive enough to enable a detailed comparative evaluation. Assistance from airport planners experienced with automatic guideway transit systems should be sought in preparing the specifications to ensure that realistic demands are placed on suppliers.

5.2.2 User Acceptance Parameters

Fare collection

- A fare collection system should be avoided if possible. This will save labour costs and avoid passenger frustration and confusion.

System attributes

- System attributes such as noise, route design, and air temperature control may not be noticed by passengers when the system is operating smoothly, but can generate complaints when there are problems.

- A unidirectional loop route generates passenger complaints when users must travel several kilometres over the complete loop just to go to the station several hundred metres behind them.

- Attention should be paid to aesthetics. This can help tremendously in projecting a favourable image of the system and gaining user acceptance.

Mixing travellers and employees
- Mixing air travellers and employees should be avoided if possible. Passengers resent riding with "the hired help" and very much resent any delays caused by employees.

5.2.3 Cost Parameters

Maintenance Costs
- In order to keep maintenance costs under control, a maintenance contract with the system supplier is essential. The major maintenance costs with automatic guideway transit systems are the power pick-up, brushes, doors, and air-conditioning. System suppliers must be required to post a performance bond.

System redundancy
- A double-track guideway loop or shuttle is desirable for system redundancy and costs only 15 per cent more than a single-track system. Care should be taken in deciding the capacity of a system. The system should provide efficient handling of peak loads as well as be flexible enough to meet eventual growth in demand. In this respect, loop systems are favoured over shuttles.

Cost recovery
- A charge to airlines and concessionaires is an appropriate means to recover system costs.

Contract costs
- Contracts with system operators on the basis of "costs plus" are desirable in providing a quality service and neutralizing windfall profits. Suppliers of new systems may be willing to absorb some of the cost overrun in order to prove their equipment and capture a share of the market.

5.2.4 Design and Operation Parameters

Winterizing the system
- The Airtrans system suppliers admit that their system will not operate reliably in winter. They

suggest that the only answer is to cover the guideway. The WEDway system at Disney World in Florida has a covered guideway. Side panels could be easily installed in winter and removed in summer. The UTDC system can operate without cover because of its linear induction motor.

Consultation with system supplier

- Involve the system supplier early in the design process. Their experience and input can save much grief, time, and money.

- If a new technology system is installed, the supplier must not be permitted to indefinitely continue developing the system during normal service operation. A fixed period of permitted "tinkering" should be included in the contract, but a fixed date must be established when the system is to be handed over to the operators. Failure to meet the target should be backed by financial penalties.

Back-up systems

- All automatic guideway transit systems require some form of back-up system in case of breakdown. Back-up systems include one or more of the following: bus, walkway, and moving sidewalks. A "mosquito fleet" of taxis for inter-terminal trips could supplement a system during peak periods for those commuters willing to pay a premium for this service. This type of operation could serve TIA well.

Maintenance personnel and schedule

- The key to controlling maintenance costs and ensuring high standards of performance and reliability is to obtain a good maintenance supervisor and maintenance team. A resourceful, knowledgeable supervisor will modify the system, scrounge parts, motivate the maintenance team, and do whatever else is required to make the system work.

- Take advantage of off-peak periods to perform system maintenance.

Comprehensibility

- A system which is simple to use minimizes confusion, accidents, and congestion. Systems which require a process of educating users (e.g., information cards for air travellers prior to landing) will not likely be successful. The system must be easily comprehensible. Assume air travellers do not know how to cope with an airport, from the moment they enter airport property to the moment their flight departs, and vice versa; then design accordingly. A system which operates similarly to an elevator is easily understood by users.

Traffic separation

- Elevated roads and exclusive bus routes can improve system performance and meet eventual growth in demand for inter-terminal shuttle-bus systems. Segregating airport bus traffic from auto traffic at curbside can significantly improve the access of both kinds of vehicles. Atlanta airport's new bus terminal is an excellent model of separation.

Fare-collection systems

- A fare-collection system, especially turnstiles, can neutralize many of the user benefits of a guideway system. Special gates for handicapped users must be installed.

- Use airport demand figures (millions of enplaning/deplaning passengers) per year rather than the actual target year in planning an implementation schedule.

Safety considerations

- Human error, rather than any component of the automatic train control system, has generally caused the few accidents which have been experienced in automatic guideway transit systems.

- In the event of an accident, the method and route of evacuation must take into account the handicapped.

Platform loading

- It is difficult for passengers with baggage to climb stairs into buses. If possible, provide platform loading, especially for the mobility disadvantaged. In this regard, guideway systems have a definite advantage over buses.

Capacity considerations

- Very few seats are required in airport shuttle vehicles. The optimum configuration appears to be a few seats for the elderly and disabled and stanchions for other passengers.

- Changes in work shifts coincide with peak passenger demand at airports. Therefore additional capacity is needed in an intra-airport transportation system to handle all movements. It may be desirable to provide two separate systems, one for inter-terminal passenger transit and another for employee transit.

Trade-off between airside and groundside transportation - Do not design the airside configuration to fit the configuration of the transportation system: fuel costs saved by minimizing airplane taxiing can equal the capital costs of the transportation system in one year.

5.3 Technology Selection

Six basic criteria were extracted from the above parameters:

- demonstrated performance;
- appropriate scale to the task;
- proven revenue operation;
- suitability for the Canadian environment;
- availability of the system;
- supplier continuity;

These criteria ruled out seven kinds of technologies:

- Commuter rail equipment: While the proximity of the Toronto transit system suggests this technology might serve airport needs, it is too heavy and inflexible for intra-airport transportation.

- Heavy rail (subway) equipment: Subway vehicles, such as those used by the Toronto Transit Commission, and their supporting system are too heavy and have a potential capacity beyond that required at TIA. Moreover, the system would be too expensive due to infrastructure maintenance and the fact that tunnels would have to be dug for it.

- Light rail (streetcar) equipment: The new Conventional Light Rail Vehicle produced by UTDC for Toronto could be used at the airport. However, their potential capacity far exceeds the needs of the airport, and their track structure and overhead power lines make them visually and operationally intrusive.

- Other group rapid transit systems: Bendix, Ford ACT, Rohr, and Cabin-Taxi are no longer commercially available. LTV Airtrans and Boeing's Morgantown

System both have problems with cold weather operations.

- Electric buses: These buses require overhead power lines and allied infrastructure which make them less flexible than fossil-fuel buses and more visually intrusive. While they are not included in the preliminary technology list below, their advantages, disadvantages, and cost are considered as part of the shuttle-bus option.
- Personalized rapid transit systems: These systems, such as the Otis, are too small for TIA's requirements. Moreover, the confined airport road network offers no advantage to these systems, which are best suited to a more complex road network.
- Automobile (taxi): The taxi has been ruled out as a primary means of intra-airport transportation, but an optional supplementary mosquito fleet of taxis should be considered as a way of serving those airport users willing to pay for personalized, immediate transportation. This fleet would operate from specially marked stands and would be restricted to, and have a monopoly on, short-haul service.

Three categories of technology were selected for preliminary evaluation:

- automatic guideway systems;
- bus systems;
- pedestrian systems.

There are three specific technology alternatives within each of these broad categories:

Category	Technology	Possible Supplier
Automatic Guideway Systems	(1) Steel Wheel on Rail	. UTDC's Intermediate Capacity Transit System (ICTS)
	(2) Rubber Tire on Concrete	. Westinghouse Transit Expressway
	(3) Compartmentalized Conveyor (i.e. Passive Vehicle)	. Disney WEDway System
Bus Systems	(1) High-Capacity Bus	. GM "Articulated" Bus
	(2) Conventional Bus	. GM "New Look" Bus
	(3) Specialized (Small) Bus	. Orion (Diesel) Bus
Pedestrian Systems	(1) Accelerating Moving Way	. Dunlop "S" type Speedway
	(2) Constant-Speed Moving Way	. Sanvik Moving Way
	(3) Pedestrian Walkways	. N/A

In addition to considering these technologies separately, there exists the possibility of combining some of them. The three most likely combinations are:

- Guideway System and Shuttle Bus: A guideway system could be used between terminals, or between the terminals and the remote parking. A separate shuttle bus could serve the employee parking areas.
- Guideway System and Moving Walkway: Due to the problems of directly serving certain areas of the airport with guideway systems (e.g., crossing the apron to serve T1), a constant speed or accelerating moving walkway could be used to connect these areas to guideway stations. In effect, these walkways would serve as collector/distributor systems for the guideway system.
- Guideway System (or dedicated shuttle bus) and Pedestrian Concourses: To improve pedestrian

transportation between terminals, and to provide an alternate or emergency route for guideway system users, a covered pedestrian concourse may be required or even desirable. This concourse, which would parallel the guideway system, would allow airport users who have the time and inclination to walk between terminals.

5.4 Thirty Technology Alternatives

Technology alternatives must be evaluated in conjunction with various right-of-way, system alignment, and mode of operation options. This will ensure that sufficient data are derived on cost, supply, and demand. Fifteen alignments were developed, of which six were retained for further analysis. Figures 5.10 to 5.12 illustrate three of these fifteen alignments, which are described in detail in Technical Working Paper Number 5. The feasible combinations of technology, right-of-way, mode of operation, and alignment alternatives resulted in thirty technology alternatives, shown in Figure 5.13.

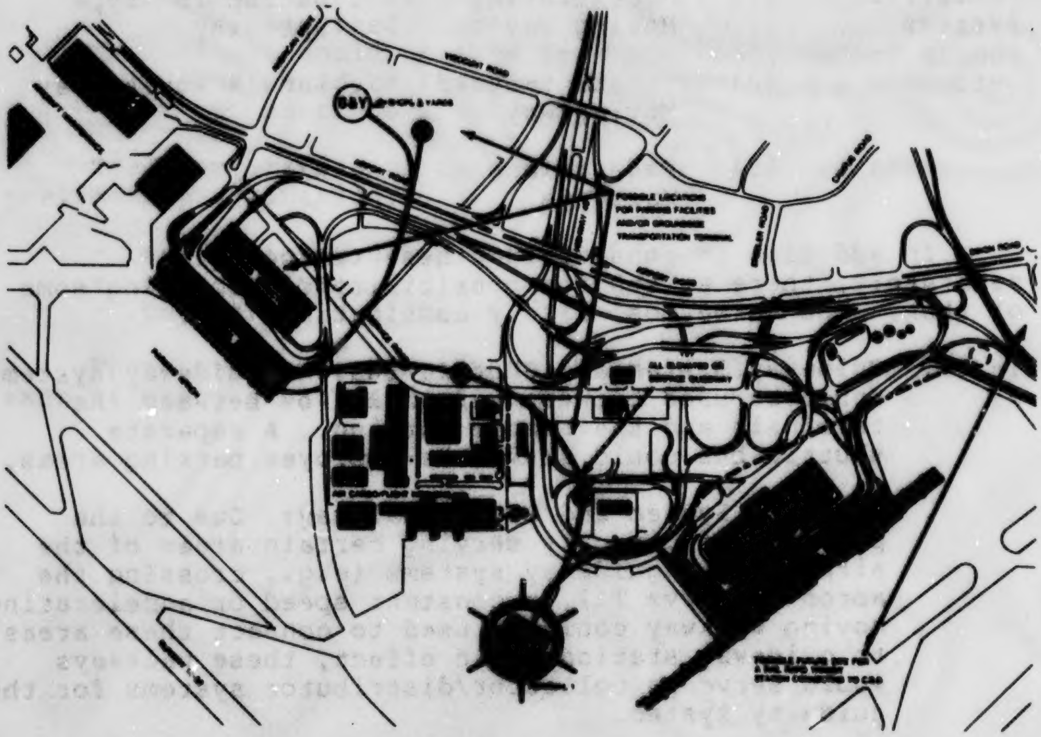


Figure 5.10 Alternative G-1: Linear Shuttle/Loop

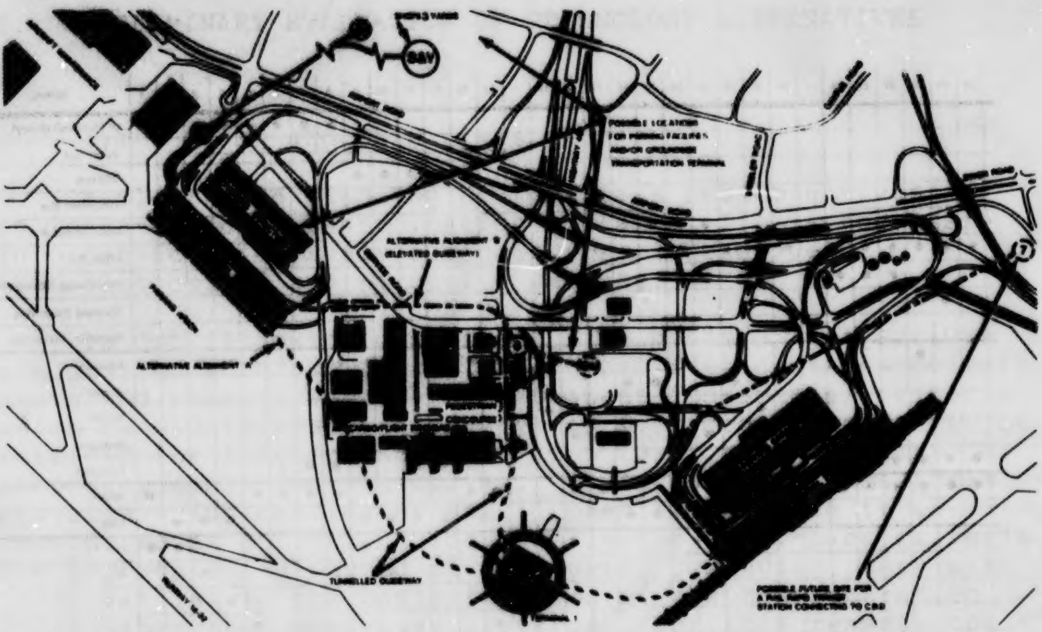

BAY
POSSIBLE LOCATIONS FOR PARKING FACILITIES AND/OR GROUNDSIDE TRANSPORTATION TERMINAL
AIRPORT ROAD
ALTERNATIVE ALIGNMENT 'B' (ELEVATED GUIDEWAY)
ALTERNATIVE ALIGNMENT 'A'
PEDESTRIAN CONCOURSE
CARGO/FLIGHT KITCHENS
TUNNELLED GUIDEWAY
TERMINAL 1
POSSIBLE FUTURE SITE FOR A RAIL RAPID TRANSIT STATION CONNECTING TO CBD
7

Figure 5.11 Alternative G-6: Tunnelled Guideway

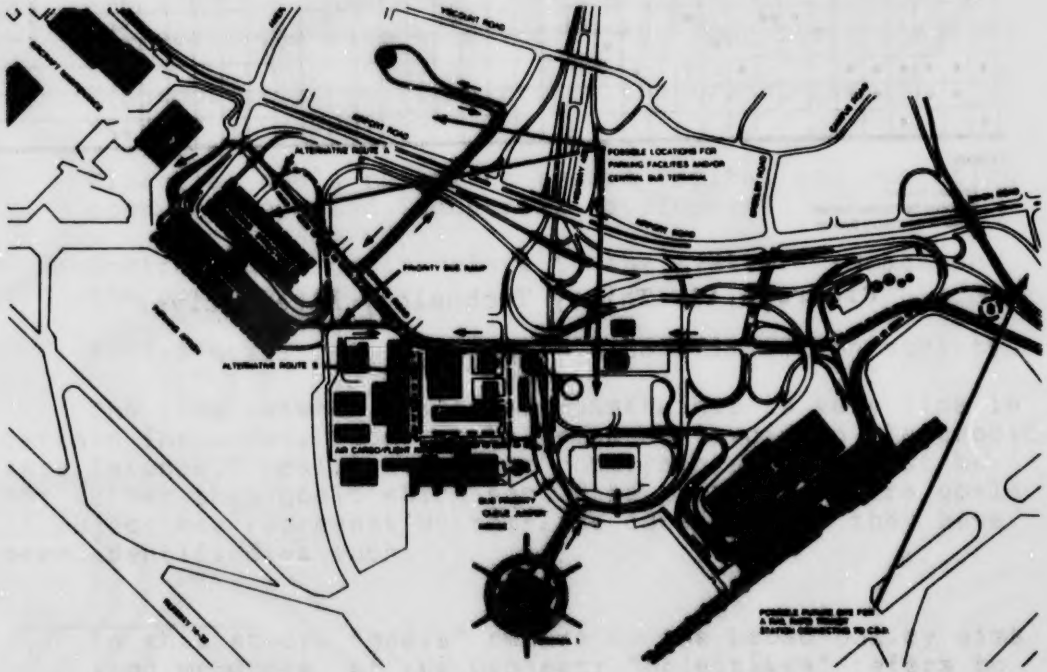

VISCOUNT ROAD
AIRPORT ROAD
ALTERNATIVE ROUTE A
POSSIBLE LOCATIONS FOR PARKING FACILITIES AND/OR CENTRAL BUS TERMINAL
PRIORITY BUS RAMP
ALTERNATIVE ROUTE B
AIR CARGO/FLIGHT KITCHENS
BUS PRIORITY QUEUE JUMPER
TERMINAL 1
POSSIBLE FUTURE SITE FOR A RAIL RAPID TRANSIT STATION CONNECTING TO CBD

Figure 5.12 Alternative B-2: Priority Busway

30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	SERIAL		
																						●	●	●	●	●	●	●	●	UTDC/Westinghouse		TECHNOLOGY
																●	●													Cable Taxi		
																		●	●	●	●									WEDway		
													●	●	●															Articulated Bus		
									●	●	●	●																		Conventional Bus		
◆	◆	◆	◆	◆	◆	●	●	●◆	◇	◇		●	◇						◇				◇							Small Bus		
			●	●	●																									Accelerating Moving Way		
●	●	●																												Constant Speed Way		
						◇			◇	◇			◇	◇			◇	◇	◇		◇	◇				◇		◇	◇	Pedestrian Concourse		
		●			●	◇			◇	◇			◇	◇		●	●◇	●◇		●	●◇	●◇		◇	●	●◇	●	●◇	●◇	Elevated		RIGHT-OF-WAY
								●			●	●							◇				◇							Shared	Surface	
							●								●															Priority		
						●			●	●			●	●																Dedicated		
●	●	●	●	●	●													●	●			●	●	◆						Tunneled		
●	●	●	●	●	●	●			●	●			●	●		●	●					●	●	●	●				●	Shuttle		MODE OF OP.
							●	●			●	●			●			●	●	●	●					●	●	●		Loop		
																	●				●							●	●	G-1		ALIGNMENT ALTERNATIVES
																				●							●			G-2		
																										●				G-3		
																●									●					G-4		
																								●						G-5		
																		●	●			●	●							G-6		
								●				●																		B-1		
							●				●				●															B-2		
						●	●◆			●				●				●◆												B-3		
									●				●																	B-4		
◆	◆	◆	◆	◆	◆			◆	◇	◇		◆	◇						◇				◇							B-5		
	●	●		●	●																									P-1		
●			●																											P-2		

LEGEND

● Primary System
◆ Required Secondary System
◇ Optional Secondary System

Figure 5.13 Thirty Technology Alternatives

6. PRELIMINARY EVALUATION OF TECHNOLOGY ALTERNATIVES

6.1 Goals and Objectives

A clear understanding of the goals and objectives[1] of an intra-airport transportation system at TIA is necessary in order to effectively evaluate the alternative technologies and system configurations.

In the following discussion, the goals and objectives are divided into two tiers. The upper tier contains primary goals and objectives. These represent fundamental criteria which candidate systems and layouts must meet in order to be retained for further analysis. The lower tier contains secondary goals and objectives. These represent desirable criteria which candidates should meet if they are to be considered as a final choice. While the lower-tier criteria are important and should be considered carefully, they are less critical to the basic function of the transportation system than the upper-tier criteria. For this reason, the lower-tier criteria are applied only to candidates which have already been shortlisted. This evaluation is conducted later in the study.

The goals can also be divided into four basic classes:

Transportation goals relate to the transportation service provided.

Financial goals relate to system capital and operating cost, energy, and industrial development.

Environmental goals relate to the system's impact on the environment.

Social goals relate to the system's impact on society.

The line between goals and constraints is very fine in certain instances. Some goals, such as "avoiding electronic interference," really represent constraints which must be met rather than goals which should be pursued. Where goals or objectives represent bottom-line constraints, they have been identified as such.

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[1] In this study, "goals" refers to the broad policy aims (end products) of the project; "objectives" refers to the means of achieving those aims.

Industry standards have been established in the passenger ground transportation field for system performance. These are primarily standards of human comfort and safety. They serve as useful baselines for assessing the absolute and relative performance of technologies and layouts. Where possible, these standards have been used in this study. Performance standards have been listed only where appropriate.

The following is a summary of upper-tier and lower-tier goals and objectives. Specific sub-objectives, measures, and performance standards are presented in Chapter 9.

6.1.1 Upper-tier Goals and Objectives

Transportation

Convenience: This goal aims at providing frequent, fast, and reliable transfer of users and employees between airport activity centres.

Access to work sites, facilities, and services: This goal aims at expanding system coverage to serve as many potential users as is practical. It is distinguished from the convenience goal because trade-offs may have to be made between coverage and convenience. A longer, less convenient service with more frequent stops may be necessary in order to provide greater coverage; or vice versa.

Reliability: This goal aims at providing a reliable service, especially to passengers making connecting flights who face a tight schedule.

Financial

Low cost: This goal aims at reducing the capital and operating cost of the system, and hence the financial burden the system places on the operator and, ultimately, on the user (assuming the user pays).

Flexibility: This goal aims at providing a system which can be incrementally and smoothly expanded to accommodate increasing traffic demands, and can be rapidly, and at a reasonable cost, altered to accommodate major unforeseen shifts in travel demand.

Social

Ease of implementation: This goal aims at selecting a system which requires the least effort in securing such social co-operation as institutional approvals, coordination, funding, and public support. The faster co-operation can be obtained, the faster the project can be completed.

Environmental

A clean, healthy environment: This goal aims at ensuring that the system does not seriously damage the environment or otherwise adversely effect the quality of life.

6.1.2 Lower-tier Goals and Objectives

Transportation

Compatibility with air transportation: This goal aims at ensuring that the system does not interfere with air operations. The layout of T1 makes this goal crucial. Certain types of potential interference, such as electronic interference, are intolerable, and hence present inflexible constraints on the choice of a system. Other types of interference involve trade-offs in time and money between air and ground transportation, and hence are negotiable. An example of the latter would be obstructing all or part of the apron area between T1 and T2.

Compatibility with surrounding transportation systems: This goal aims at ensuring that the system contributes to improving mobility to, from, and within the airport, in co-operation with transportation planned or provided by surrounding communities and the Ontario government.

Comprehensibility: This goal aims at providing a system which travellers and visitors (many of whom are unfamiliar with the airport) will readily understand. The design of information systems can do much to promote this goal, however some technologies (e.g., dedicated right-of-way, rather than operation in mixed traffic) and system layouts (e.g., shuttles or loops, rather than multiple paths) are inherently simpler for users to understand. Quick and clear understanding is essential for effective use.

Convenience of luggage handling: This goal aims first at providing air travellers with a convenient method of handling their luggage, and second at providing an efficient way of handling air cargo, goods, and waste, where necessary. Certain systems are inherently better at handling luggage than others. And, while road systems will continue to be the principal means of transporting goods, there are certain situations in which it might be helpful to move goods by the intra-airport transportation system. One example of this would be air freight parcels arriving by airport bus at a groundside transportation terminal. Nevertheless, while a goods-carrying capability is certainly an asset, it must remain a secondary consideration.

Comfort: This goal aims at ensuring that using the system will be a pleasant experience rather than an onerous one. To a considerable extent, comfort can be designed into any system, for example, by installing air-conditioning. However, this task is inherently easier and less costly for some technologies than for others. Comfort criteria play an important role in constraining the physical layout and operational policies of systems, and it is essentiel that these comfort criteria be considered when comparing alternative systems. This will ensure that the comparisons are fair. The technologies and layouts compared should therefore meet all of the comfort criteria; if one does not, the importance of that exception should be carefully weighed in comparing alternatives.

Financial

Preserve or increase sources of airport revenue: This goal aims at supporting Transport Canada's policy of user pays.

Conserve energy, particularly fossil fuels: This goal aims at supporting federal and provincial government policies to reduce energy consumption.

Social

Safety and security: This goal aims at providing safe and secure transportation for all users. This would reduce the loss of life and suffering caused by accidents, and emotional stress caused by users' worries about safety. Some systems are inherently safer than others, for example, those using closed-circuit television surveillance.

Equity of access: This goal aims at ensuring that all members of society with a legitimate need to use the system have access to it. Providing access for the handicapped is a matter of good design (e.g., wheelchair tie-downs), but certain technologies and system layouts are inherently more accessible than others. A platform loading ICTS, for example, is far more accessible than a bus with a stairwell.

Environmental

A pleasant environment: This goal aims at ensuring that the system does not detract from the quality of life in the area through which is passes.

6.2 Evaluation Procedure

Technical Working Paper Number 5 defines technology alternatives in terms of four characteristics: (1) specific technology; (2) type of right-of-way; (3) mode of operation; and (4) alignment. How well each technology alternative achieves each of the goals and their objectives depends upon one or more of these characteristics. For example, the "accessibility" goal is primarily influenced by the "alignment" characteristics. Assessing each of the fifteen alignment alternatives for the coverage they provide in effect assesses all thirty technology alternatives. To simplify the evaluation procedure a simple ranking procedure is used, with the following definitions:

Symbol	Definition
5 or ●	Greatly exceeds the requirements of the objective; provides a very high quality service; significantly minimizes negative impacts.
4 or ◕	Exceeds the requirements of the objectives; provides a good quality of service; few negative impacts.
3 or ◓	Meets all requirements of the objective; provides a reasonable level of service; acceptable negative impacts.
2 or ◔	Meets the minimum acceptable standard of performance and service; negative impacts at the threshold of acceptance.
1 or ○	Fails to meet minimum standards of performance, service, environmental protection, etc.

The evaluation procedure involves four steps:

Step 1: For each objective of the goal being evaluated, identify which characteristic (or characteristics) of the definition of the technology alternative is (are) relevant. Example: The "reliability" goal has the objective of "reducing time to recovery" which is determined primarily by the "mode of operation" characteristic of the systems under study.

Step 2: Assess how well each sub-category of the characteristic identified in Step 1 performs against the objective in question, and assign an appropriate rank. Example:

Mode of Operation	Performance	Rank
Shuttle	Poor	2
Loop	Excellent	5

Step 3: Apply the evaluation carried out in Step 2 to all of the technology alternatives. Example:

Objective	Alternative		
	1 Shuttle	2 Loop	3 Loop
"Reduce time to recovery"	2	3	5

Step 4: Aggregate the objectives into a single weighted measure of how well each technology alternative meets each of the seven upper-tier goals. The principle of aggregation is based on the weakest-link theory; in other words, the overall rating assigned to each technology alternative is determined by selecting the lowest of the individual objective ratings, then comparing this with the other ratings to determine how much the overall rating should be raised to reflect better performance in the achievement of the other objectives. This is very much an exercise in judgement. Example:

	Alternative 1	Alternative 2
Objective 1	2	2
Objective 2	3	5
	.	.
	.	.
Goal	.	.
Measure	2	2

6.3 Evaluation Results

The preliminary evaluation of the technology alternatives is described in Technical Working Paper Number 7 and summarized in Table 6.1. Row 8 of this table presents an overall ranking of the alternatives. The heaviest weight is given to cost and convenience. The least weight is given to environmental impact and accessibility, because all systems provide adequate accessibility and none seriously degrades the airport environment, at least compared with other activities in the area. Symbols are used to make comparing the alternatives easier.

Based on Row 8, the preliminary evaluation recommended:

That only three technologies be retained for further evaluation:

1. The intermediate capacity elevated guideway (ICEG), such as the UTDC system or the Westinghouse system (Technology 1, 7, 8).
2. The light tunnelled guideway (LTG), such as the WEDway (Technology 11, 12).
3. The shuttle bus (Technology 15 to 24).

That only alignments G-1 and G-6 be retained.

That the shuttle and loop mode of operation be considered for the intermediate capacity elevated guideway and only the loop mode of operation for the light tunnelled guideway.

That both tunnelled and elevated guideway options be considered for the guideway system and all surface right-of-way alternatives be considered for the bus alternatives.

Table 6.1 Preliminary Evaluation Summary

	TECHNICAL ALTERNATIVE NUMBER																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1. CONVENIENCE	◕	●	◕	●	◕	◔	●	●	◕	◔	●	●	◔	◕	◕	◕	◕	◕	●	●	◕	◕	●	●	◕	◕	◕	◔	◔	◔
2. ACCESSIBILITY	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	◕	●	●	◕	●	●	●	◔	◕	◕	◔	◔	◔
3. RELIABILITY	◕	●	◕	◕	●	◕	●	◕	●	●	●	◕	◕	◕	●	●	●	◕	◕	●	●	◕	◕	●	◔	◔	◔	◔	◔	◔
4. COST	◔	○	○	○	◔	○	◔	◔	◔	◔	◔	◔	◔	◔	◕	◕	◕	●	●	●	●	●	●	●	◕	◕	◔	◕	◕	◔
5. FLEXIBILITY	◔	◕	◔	◔	◔	◔	◔	◔	◕	◕	◕	◔	◔	◔	●	●	◕	◕	◕	◕	◕	◕	◕	◕	◔	◔	◔	◔	◔	◔
6. EASE OF IMPLEMENTATION	●	◕	◕	◕	◕	◕	◕	◕	◔	◕	◔	◔	◔	◔	◕	◕	◕	●	●	●	●	●	●	●	◕	◕	◕	◔	◔	◔
7. ENVIRONMENTAL ASSESSMENT	◕	◕	◕	◕	◕	◕	●	●	●	●	●	●	●	●	◔	◔	◔	◔	◔	◔	◔	◔	◔	◔	●	●	●	●	●	●
8. OVERALL	◔	○	○	○	○	○	◔	◔	○	○	◔	◔	○	○	◕	◕	◕	◕	●	●	◕	◕	◕	◕	○	○	○	○	○	○

7. THREE TECHNOLOGY ALTERNATIVES FOR TORONTO AIRPORT

This chapter describes in detail the three shortlisted technologies recommended by the preliminary evaluation and looks at the architectural implications of these technologies for existing and proposed structures at TIA. The three technologies are: the intermediate capacity elevated guideway, the light tunnelled guideway, and the shuttle bus. Each is described using data from typical manufacturers: UTDC's Intermediate Capacity Transit System and the Westinghouse Transit Expressway for the intermediate capacity elevated guideway; the Disney-Turner WEDway for the light tunnelled guideway; and the Orion and General Motors buses for the shuttle bus. Specific suppliers are named to lend realism to the analysis and should not be interpreted as an endorsement of a supplier for final selection.

This chapter does not examine the enormous amount of descriptive technical data produced by the manufacturers. Technical Working Papers Numbers 11a, 11b, 11c, and 11d contain this data as well as layout and design information about how each technology could be applied at TIA. The working papers also provide details of each system's level of passenger comfort, energy consumption, luggage and cargo capabilities, costs, implementation schedule, and environmental impact. Technical Working Papers Numbers 13a and 13b contain additional information about the impact of each system on existing airport facilities and their architectural requirements.

The data furnished by the suppliers were not directly comparable but have been presented on a common basis in the detailed evaluation in Technical Working Paper Number 14, and summarized in Chapter 8.

7.1a UTDC's Intermediate Capacity Transit System

The Intermediate Capacity Transit System (ICTS) consists of short trains of vehicles operating automatically at short station headways. Vehicles have steel wheels and a steel rail suspension, but have a number of features which reduce noise. A linear induction motor for traction and braking ensures all-weather performance. Vehicle performance and the flexibility of a moving block train control system permit safe, reliable operation at low station headways, and consequently allow reductions in platform length and station size.

7.1a.1 System Layout

ICTS would operate in the so-called airport people mover mode, described in Technical Working Paper Number 11B. It would operate over an elevated guideway, generally along the alignment shown in Figure 7.1. The system would be implemented in three phases.

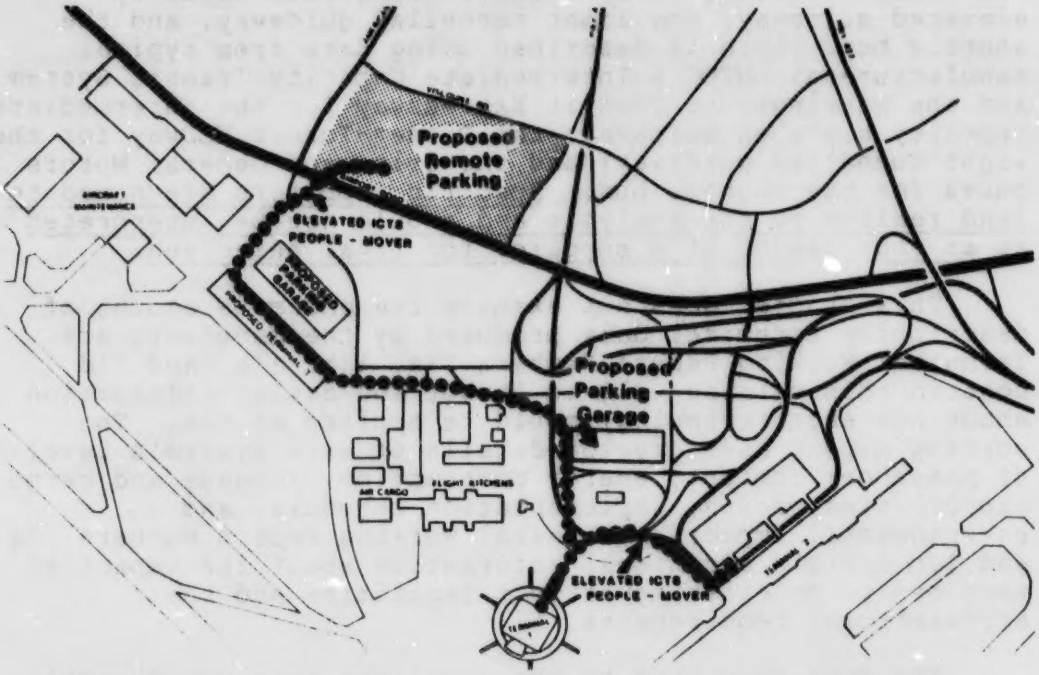
Proposed
Remote
Parking
AIRCRAFT
MAINTENANCE
ELEVATED ICTS
PEOPLE - MOVER
PROPOSED
PARKING
GARAGE
PROPOSED TERMINAL 7
Proposed
Parking
Garage
AIR CARGO
FLIGHT KITCHENS
ELEVATED ICTS
PEOPLE - MOVER
TERMINAL 2
TERMINAL 1

Figure 7.1 ICTS Site Plan for TIA

Phase 1 would consist of a simple shuttle service operating between T1 and the proposed parking garage just north of the administration building. A single train would operate bi-directionally over a single, elevated guideway. Vehicles would be serviced and maintained at a small maintenance facility on a spur track, alongside the station at the proposed parking garage. This maintenance area would be fully integrated into the parking structure and capable of handling a maximum of two vehicles. The maintenance and main tracks, as well as the station, would be located at roughly the second level of the parking garage, while the station at T1 would be at the first level. There would be two lanes entering T1, with a cross-over track and a stub-end on one lane to permit future expansion of the system to T2 and beyond.

Phase 2 would add to Phase 1 a single-lane, elevated shuttle service between T1 and T2. The T2 station would be situated above the departures level road, and connect to the terminal building and its parking garage. The guideway would end at this station but be situated in such a way as to allow expansion along the length of T2.

Phase 3 would connect the proposed parking garage north of the administration building with the proposed T3. The T3 station would be situated in the same relative position as in T2, assuming T3 is identical to T2. The guideway would continue through this station for the full length of T3, then turn right to cross Airport Road and end at the proposed remote parking area station.

This alignment eliminates the need for a turn-back at T3, which would require a dual guideway, cross-over tracks, and switches. In addition, it facilitates the integration of a future, permanent maintenance and storage facility, perhaps in the T3 parking garage or in the proposed remote parking area.

7.1a.2 Station Impacts

The first three phases would include at least five stations and one, or perhaps two, maintenance facilities.

Terminal 1 Station

As part of Phase 1, a dual guideway would be provided to allow for eventual two-way shuttle service between the administration area and T1 and T2. Two cross-over tracks and switches would be included just outside the T1 building to allow this mode of operation. The guideway closest to T2 would be stub-ended for Phase 1, at a point just east of the aircraft taxi area.

The development of the T1 station would involve three modes of vertical transportation, using elevators and stairs. Escalators have not been considered in the vicinity of the T1 station, because they would seriously disrupt the internal processing of air passengers on the departures and arrivals levels in T1.

The first vertical transportation mode would use the existing T1 elevators. These are situated adjacent to the station and already provide convenient vertical movement. They are, however, currently operating at capacity. A second vertical transportation system would therefore be necessary once Phase 1 was implemented.

The second vertical transportation mode would consist of two new elevators connecting the station with the departures and arrivals levels of T1. They would be installed adjacent to the existing elevators. This location would minimize disruption to airport passenger flows at the arrivals and departures levels. Access to, and directions for, these new elevators would be consistent with signs for the existing elevators. Access to the existing elevators would continue to be available through the sliding doors between the station platform and the parking garage.

The third vertical transportation mode would be the existing stairs. They would be used by passengers travelling between the station and the departures and arrivals levels.

There remains one potential technical problem in this location of the elevators. The floor diaphram on the first level of the parking garage terminates at the front edge of the elevator shaft. Thus, the floor and edge beam connection to the elevator shaft may be needed for lateral bracing on the first level. If so, alternative locations for new station elevators would have to be selected.

Terminal 2 Station

The guideway would be parallel to the longitudinal axis of T2. It would be placed on columns above the departures level roadway, between the terminal and the parking garage. Although the guideway would end at a safe distance beyond the platform at this station, its positioning would permit a convenient future extension along the length of T2. The extended guideway could include another station at the east end of the terminal and an eventual connection to Toronto's rapid transit system, if it were extended.

Passengers would connect between the station platform and the terminal via a walkway from the existing stairshaft atop the terminal roof and running above the departures level roadway. Escalators could be placed in the stairshaft or conventional stairs supplemented by elevators might be adequate.

An optional ramp or escalator could be provided to connect the transit station with the passenger walkway to the parking garage. Incorporating this feature would depend upon the results of a value analysis of the direct access to the parking garage as a function of the number of passengers expected to exercise this option. Existing data indicate that most passengers using the transit system would be making inter-airline connections; therefore a ramp or escalator directly serving the parking garage would not be cost-effective at this stage.

Figure 7.2 shows that no clearance problems would be encountered in fitting either the guideway or vehicles into the existing T2 infrastructure. The extensive use of glass on the roof-top walkways and station platform would offer passengers an interesting, panoramic view of the ICTS vehicles and aircraft in operation. More importantly, the view would allow passengers to better orient themselves with important airport and transit system functions. Skylights or glass roofs in these areas would also maximize light entry and increase visibility.

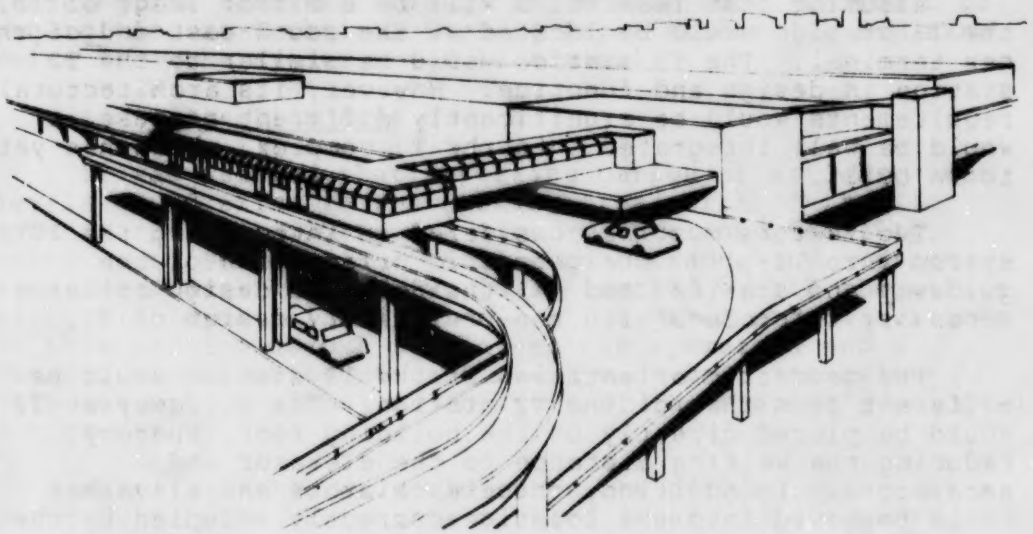

Figure 7.2 Isometric View of the T2 Station

UTDC understands that there is no mechanical equipment in the stair towers at the west end of T2. Thus, escalators could be installed in T2 with a minimum impact on the building. The existing elevator at the west end of the terminal is one of four elevators already serving the elderly and handicapped, and is the only elevator serving Gates 71 through 89. This elevator would be extended to the roof to also serve the transit system.

Residual decisions would be required to resolve the major structural issues at this station, for example the exact location of columns to support the station platform. The roadway currently sits on individual columns with sliding bearings at the top of each, making continuation of these columns to the station platform impossible. The columns which pass through the roadway would therefore have an annular ring around them to allow expansion or contraction of the roadway deck.

The UTDC station concept uses a self-contained structure to connect the transit platform to the tower in T2. Except for construction loads, no long-term loads would be placed on the existing cantilever roof over the departures level roadway. Construction details and allowable loads during construction would be developed jointly with TIA and Transport Canada.

Terminal 3 Station

Assuming that Terminal 3 will be a mirror image of T2, the T3 station would be located at the south-east end of the new terminal. The T3 station would be similar to the T2 station in design and function. However, its architectural requirements would be significantly different because it would be well integrated into the T3 complex, which has yet to be built.

Two factors must be considered in integrating the ICTS system into T3: (1) the geometric orientation of the guideway and station; and (2) the detailed design criteria necessary to proceed with the preliminary design of T3.

The geometric orientation of the T3 station would be different from that of the T2 station. The guideway at T3 would be placed directly on the building roof, thereby reducing the walking distance to the elevator and escalators. In addition, these escalators and elevators could be moved into the location currently occupied by the stairwells in T2. This would further reduce the walking distance from the station to the vertical transportation system. The escalators and elevator would be oriented to provide easy access for all passengers, including the elderly and the handicapped.

To further improve passenger flow in and around T3, a pedestrian bridge could be built under the departures level roadway, linking the proposed parking area with the terminal. While the bridge would provide an intermediate mezzanine above the arrivals level, it would also allow pedestrians to travel between the parking area and the terminal without mixing with departures level vehicule traffic, as currently occurs at T2. Including such a bridge might require that the building floor-to-ceiling height at the arrivals level be greater than that at the departures level.

Another important factor in designing the T3 station would be how to isolate the system's noise and vibration from the terminal building. This could be best achieved by making the station an integral part of the terminal structure, while placing the guideway on an independent structure, and using common floorings for both.

Although vibrations from ICTS trains would be extremely minor, due to the light weight of the vehicles, even minor vibrations could be transferred to the ground without affecting the terminal structure by using separate columns. These would provide an independent path to the ground for all but the smallest vibrations. Secondary vibrations reaching the terminal through any common footings would be negligible, as Technical Working Paper Number 11b explains. Noise from the system would be minimal.

Administration Area

It was assumed that a parking garage of at least four levels would exist in the parking area north of the administration building. A minor maintenance facility, which would serve as the vehicle maintenance and storage area for Phases 1 and 2, would be located within the garage, along with a mainline station. All figures and discussions in this section assume single-vehicle operation and a Phase 2 construction stage, unless mentioned otherwise. This assumption allows an analysis of the station's critical design stage.

Mainline vehicles would enter the parking garage at a point just below the garage's third level. A guideway turnout for the maintenance and storage track would be provided just outside the garage[1]. This track would enter at the same level as the mainline. For Phase 2, both tracks would end at the rear of the enclosed maintenance and storage area, with sufficient track runouts and dynamic buffers provided for safety. When access to T3 is required, the mainline track could be extended through the remainder of the garage and out toward T3.

The two-level maintenance and storage facility would enable personnel to perform all vehicle servicing and most maintenance functions, such as detrucking and replacement of the linear induction motor. Major maintenance, such as replacement of trucks, would be performed by positioning vehicles outside the garage on the maintenance track and lowering them to the ground with a rented crane, for transport to a facility in the Toronto area. This type of major maintenance would likely occur every few years, and could be carried out at existing maintenance shops such as those operated by GO Transit or the Toronto Transit Commission.

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[1] The maintenance facilities could be accommodated elsewhere if the garage is not built.

Remote Car-parking Station

The station in the remote car-park beyond Airport Road would be situated at-grade, as shown in Figure 7.3. The at-grade guideway would run at the same level as the station platform for its full length. An adequate guideway runout and dynamic buffer would ensure safe stopping conditions. Vehicles would simply reverse direction at this station, once the required dwell had been completed.

Although the station would be similar in size to those in the airport's terminals, the platform would only be high enough off the ground to meet the vehicle floors, as shown in Figure 7.3.

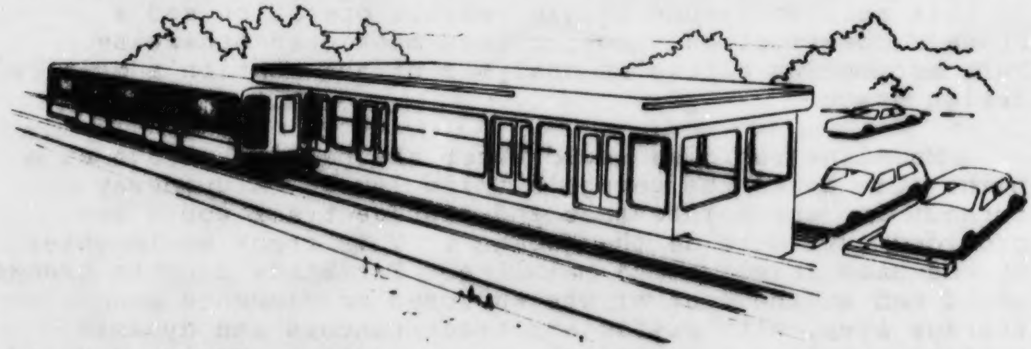


Figure 7.3 Isometric View of the Remote Car-park Station

Passengers would access the station from the surface car-park by either the short flight of stairs or by the ramp. The ramp would also be used by the elderly and the handicapped.

Given a standard, at-grade guideway slab of 200 metres, and assuming the slab and station footings are poured at the same elevation, the station platform would be located about 1,130 millimetres above ground level, sufficient to meet the vehicle floor. The platform itself would be about 120 square metres in area.

7.1a.3 Full System Maintenance and Storage Facility

Technical Working Paper Number 11b describes the concept for a full transit system maintenance and storage facility at TIA. The concept is based on similar designs developed for ICTS systems, but takes into account TIA's space and architectural requirements.

The facility could be tailored to fit either inside a building, such as the proposed T3 parking garage, or in an open area, such as the remote car-park. In either case, the system's all-weather capabilities eliminate the need for a protected area for maintenance or storage. In addition, the facility could be situated either at-grade or elevated.

Figure 7.4 View From T1

7.1a.4 Guideway Visual Features

Viewed from the T1 parking garage (Figure 7.5) the guideway and vehicles would appear as a slender, unobtrusive ribbon, supported on long, relatively shallow, and lightweight concrete beams. This minimal, yet pleasing, visual impact of the guideway and vehicles is even more noticeable at closer range.

Figure 7.5 Approach to T1

7.1a.5 Management Considerations

The Urban Transportation Development Corporation Ltd. (UTDC) was established in 1974 by the Ontario provincial government. UTDC would form a joint venture with Kilmer Van Nostrand Ltd. (KVN) to assume responsibility for overall project management, control and administration, and owner liaison. KVN is a large North American general contractor based in Toronto.

Figure 7.6 T2 Station

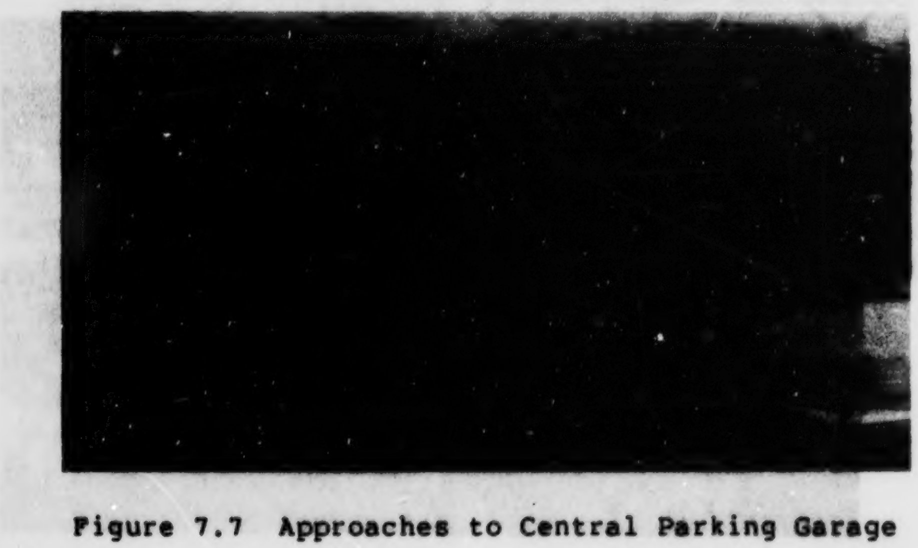


Figure 7.7 Approaches to Central Parking Garage

7.1b Westinghouse Transit Expressway

Figure 7.8 shows the Westinghouse Transit Expressway, another airport people mover system. At TIA this would consist of a domestic roadway approximately 1,655 metres long, extending from T1 to T2 and T3. The roadway would have concrete running pads and a center guidebeam. The electrically propelled, totally automated, air-conditioned vehicles would comfortably carry 70 passengers and could operate 24 hours a day. Simulated performance tests show that the system would exceed the Demand Scenario Four requirements at TIA. This simulation assumes a maximum vehicle speed of 48 kilometres per hour. The optimum speed for the system at TIA might exceed 48 kilometres per hour, depending on the system parameters and configuration.

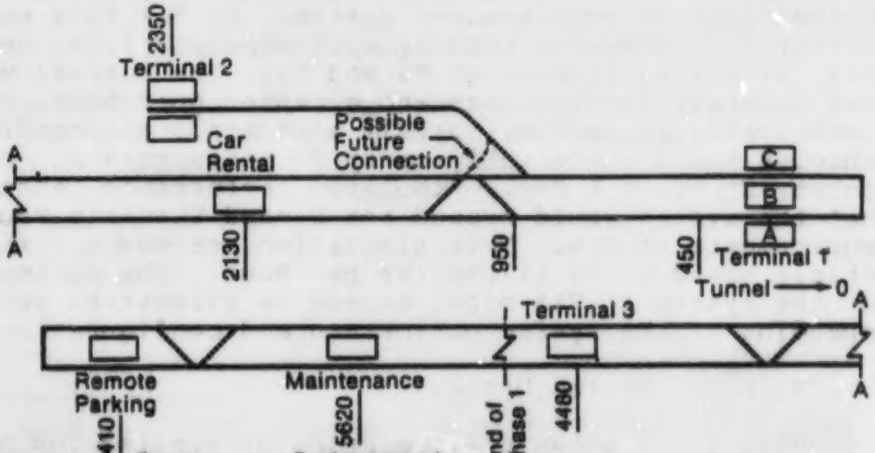
7.1b.1 System Design

Figure 7.9 shows the operating strategies for Demand Scenario Four. Figure 7.10 shows a Westinghouse alternative.

7.1b.2 Facilities Impact and Architectural Requirements

There is no significant difference in the facilities impact of the ICTS and Westinghouse systems. A separate examination of the Westinghouse system was not considered to be warranted and hence its facilities impact and architectural requirements are assumed to be the same as those of the ICTS.

Figure 7.8 The Westinghouse Transit Expressway


2350
Terminal 2
Possible
Future
Connection
Car
Rental
A
A
C
B
A
2130
950
450
Terminal 1
Tunnel ⟶ 0
A
Terminal 3
Remote
Parking
Maintenance
6410
5620
End of
Phase 1
4460
A

Route	Performance*
Terminal 1 to 2	1 Two-car Train 4.75 Minute Headway 1,780 Passengers per Hour Each Direction
Terminal 1 to 3	4 Two-car Trains 2.2 Minute Headway 3,800 Passengers per Hour Each Direction
Terminal 3 Round Trip	6 Two-car Trains 2.47 Minute Headway 3,410 Passengers per Hour Each Direction

*Based on 70 Passengers per Vehicle

Figure 7.9 Westinghouse's Demand Scenario Four System

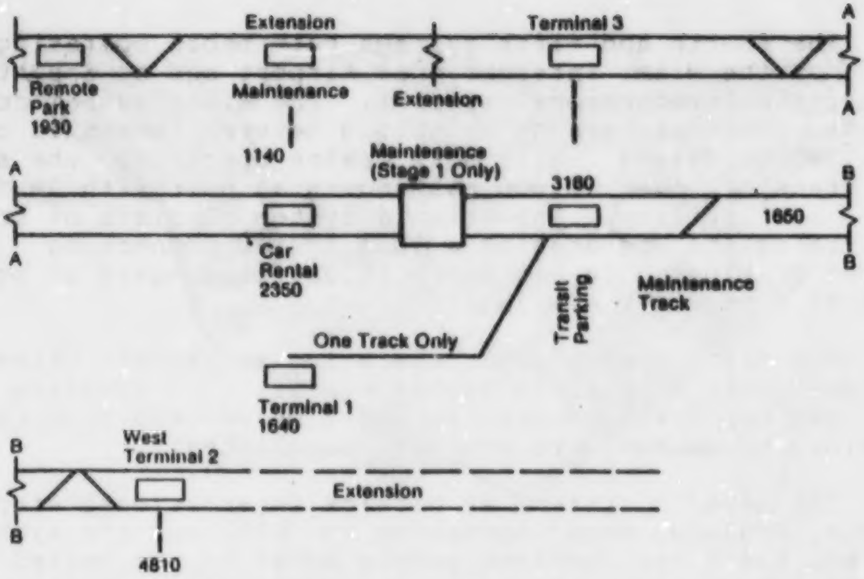

Extension
Terminal 3
A
Remote Park 1930
Maintenance
Extension
A
1140
A
Maintenance (Stage 1 Only)
3160
B
1650
A
Car Rental 2350
B
Transit Parking
Maintenance Track
One Track Only
Terminal 1 1640
B
West Terminal 2
Extension
B
4810

Figure 7.10 Westinghouse's Alternative System

7.1b.3 Management: Background

The methods and procedures employed by Westinghouse in controlling and administrating a project as complex as TIA's intra-airport transportation system have been developed and refined through many years of field experience with similar and even more complex programs.

Backed by 80 years of experience in the design and supply of propulsion and automatic train control equipment, Westinghouse developed its people mover technology in the mid-1960s. It developed a comprehensive test program for a prototype of the concept on a 3.2-kilometre test track at South Park near Pittsburgh.

Since then, Westinghouse has placed eight systems in service:

The first of these, built at the Tampa International Airport, began operating in 1971. By 1982 over 120 million persons had been carried by this system; its system availability exceeded 99.9 per cent.

The second system, longer and more sophisticated than the first, began operating at the Seattle-Tacoma Airport in 1973.

The third system began operating in May 1975, at Busch Gardens' Theme Park in Williamsburg, Virginia.

The fourth and fifth systems both began operating in 1980, at the Miami International Airport and at the Atlanta Hartsfield International Airport. The Miami system consists of two, three-car trains shuttling between terminals on parallel guideways. With both trains operating, the system can transport over 12,000 passengers an hour with 99.8 per cent availability. The Atlanta system consists of three-car trains and operates on a loop system connecting eleven stations. It can carry 18,000 passengers an hour with 99.6 per cent availability.

The sixth system began operating at the new Orlando International Airport in September 1981. It consists of two, two-car trains which transport passengers from the main terminal to each of two separate satellites.

The seventh system, at Gatwick International Airport in London, England, began operating in 1983, and the eighth system, the first downtown people mover in the United States, in Miami, Florida, is scheduled to begin operating the end of 1984.

7.2 Disney-Turner WEDway

The WEDway system consists of small, fully-automated trains running through underground tunnels. Each car holds twelve people. The trains are completely passive, meaning all services such as linear induction motor propulsion, air-conditioning, lights, and intercoms, are provided in the tunnels and stations.

7.2.1 System Layout

Figure 7.11 shows how the proposed route would link stations at T3, T1, T2, and the T2 parking garage. The route could be extended to a remote parking facility and/or a rapid transit station.

The existing pedestrian tunnel between T1 and T2 would be used to form part of the link between these two stations. Figure 7.12 illustrates how the tunnel would look.

7.2.2 Station Impacts

Terminal 1

The area affected by a WEDway station in the T1 basement is shaded in Figure 7.13. A new tunnel could be built from the existing pedestrian tunnel, under the international airside corridor, and up to the basement level. A similar route would be followed on the west side

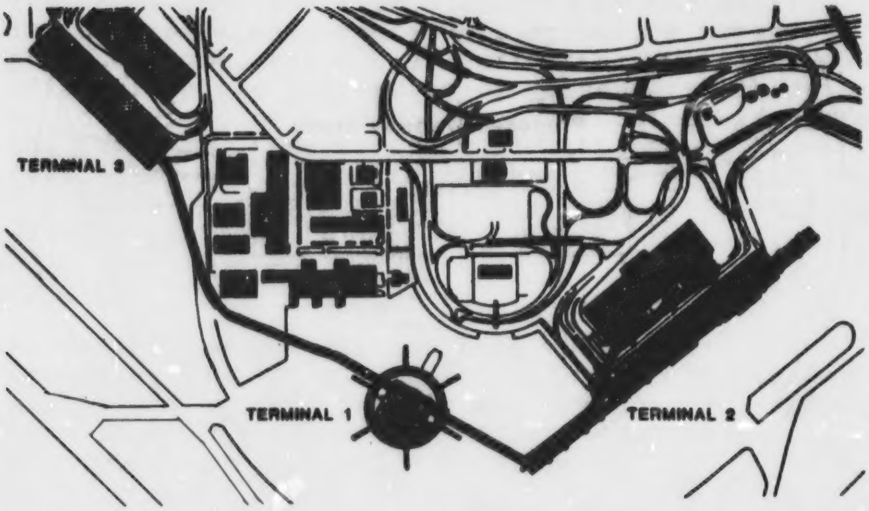

TERMINAL 3
TERMINAL 1
TERMINAL 2

Figure 7.11 Proposed WEDway Route

Figure 7.12 WEDway in the Existing Tunnel Between T1 and T2

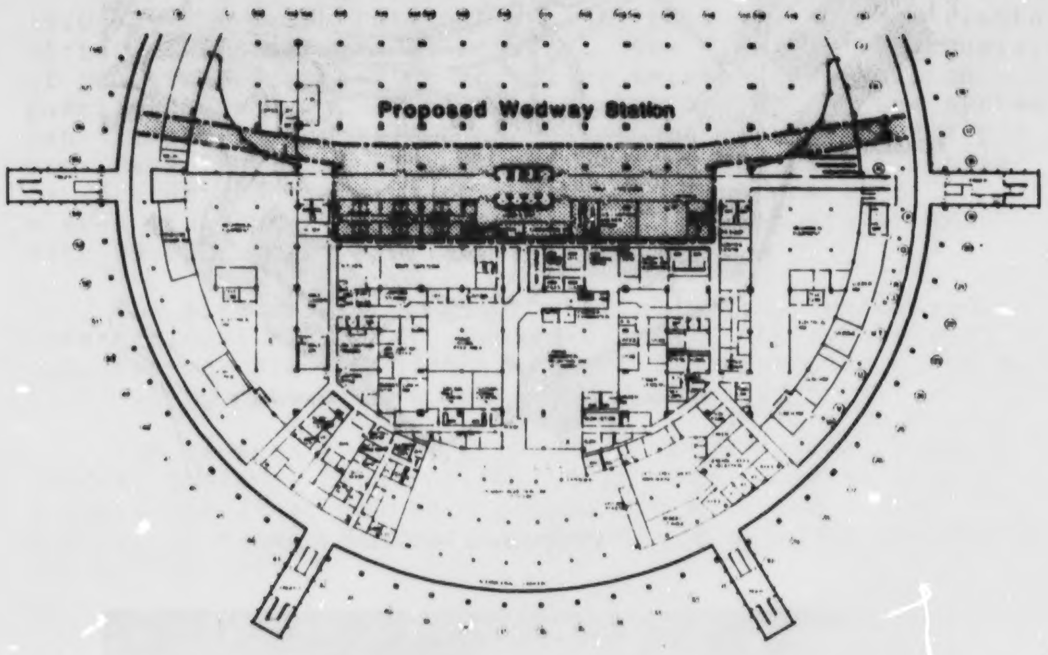


Figure 7.13 Existing Basement Plan for T1

of the terminal to extend the transit route to T3. Preliminary analysis has demonstrated that the size and bearing requirements of the column footings make a sub-basement tunnel and station unfeasible. In addition to the transit station, space has also been reserved for a control room and maintenance facility.

Three factors must be considered in integrating a WEDway station into T1: (1) relocation of existing functions; (2) supplementary vertical transportation from the basement to the enplaning and deplaning levels; and (3)emergency exits.

Relocation of Existing Facilities:

The basement and deplaniing level of T1 are currently undergoing extensive reconstruction to upgrade capacity and level of service. Although some remedial work is being done in the area affected by the proposed station, it is not being modified directly as part of this program. The shaded area in Figure 7.13 is almost one metre higher than the adjacent area to the south, thus reducing its importance as expansion space.

The rooms that would be displaced by the station include conference rooms, a playroom, a nursery, storage rooms, and a U.S. Customs area. Although not critical to the processing of passengers, these spaces would have to be eliminated or relocated elsewhere in the terminal. Due to space limitations at T1, relocation would require further detailed study outside the scope of this report. This could influence the acceptability of this scheme.

Vertical Transportation

Accessing the new station from the enplaning and deplaning levels is a challenging problem because the existing elevators are already overloaded. Space on both levels is extremely constrained. Two vertical transportation options were studied:

Option A: Escalators

Escalators are the best way of transporting people vertically in an airport terminal. They are more efficient than elevators and they are better suited to passenger orientation and flow. Option B: New Elevators

This option displaces the bar on the deplaning level (considered less critical than the car rental booths) and an airline ticket counter on the enplaning level. Although new elevators would compromise circulation between floors more than escalators would, elevators would be more easily integrated into the building fabric and are therefore preferable. Access to the basement by the existing elevators would be discontinued, thereby improving service to the parking levels from the enplaning and deplaning levels.

Emergency Exits

T1, designed in 1958, does not conform to current codes governing emergency exits. This has been a source of continuing concern to the Dominion Fire Commissioner's Office. All proposals for modifications to T1 take this concern into consideration.

The present exit route south of the proposed station is up ramps at either end of the concourse and out onto the car-park. Since this route would be intersected by the WEDway tracks to T2 and T3, an alternative exit route would have to be devised in order to make this station viable. The Dominion Fire Commissioner's Office has rejected the concept of a level crossing with automatic doors or gates on the grounds that it would be unsuitable and undependable. However, the commissioner's office has approved in principle the idea of introducing new stairways down to tunnels below the tracks; these tunnels would run between the existing footings and connect with stairways leading back up to the car-park.

Two exit routes from the station platform and control room area would also be necessary. The existing central stairway cannot be considered an acceptable exit because of its width. Two additional stairs and tunnels would have to be constructed to provide access to the parking area.

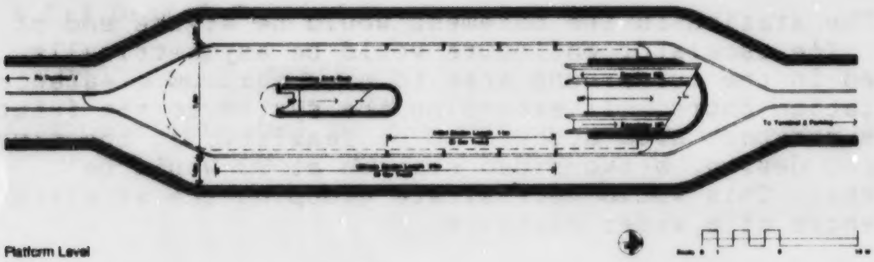
Terminal 2

A new tunnel would be constructed below the T2 service road to link the existing pedestrian tunnel with the proposed new station in the courtyard adjacent to the west end of the arrivals concourse.

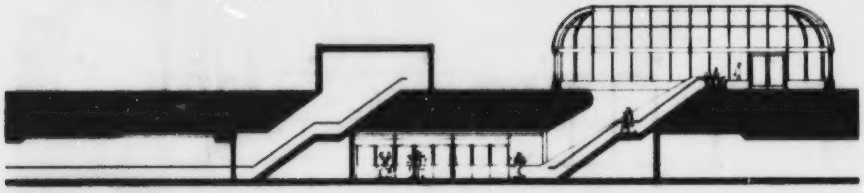
The stations for the T2 parking garage and a remote car-park would be similar in design. The platform levels would have to include space for a track turnaround. The size of the ground-level enclosure, which is minimized in the T2 courtyard because of space restraints, could be enlarged somewhat in the other two stations to provide additional waiting area.

Providing a station at the east end of the T2 garage is questionable. Preliminary site analysis has revealed tight space constraints between the access roads and ramps and the parking garage footing. The surface car-park east of the garage could be developed as a station, but pedestrian connections to the garage and terminal would be long and costly. Studies of the garage's potential as an overload facility for T1 have indicated there is surplus space for current T2 demands. However, it would be difficult to dedicate a specific area with a conveniently located WEDway station.

Deletiing the T2 garage station would necessitate building a turnaround track at the station at the west end of T2.



Platform Level



Section

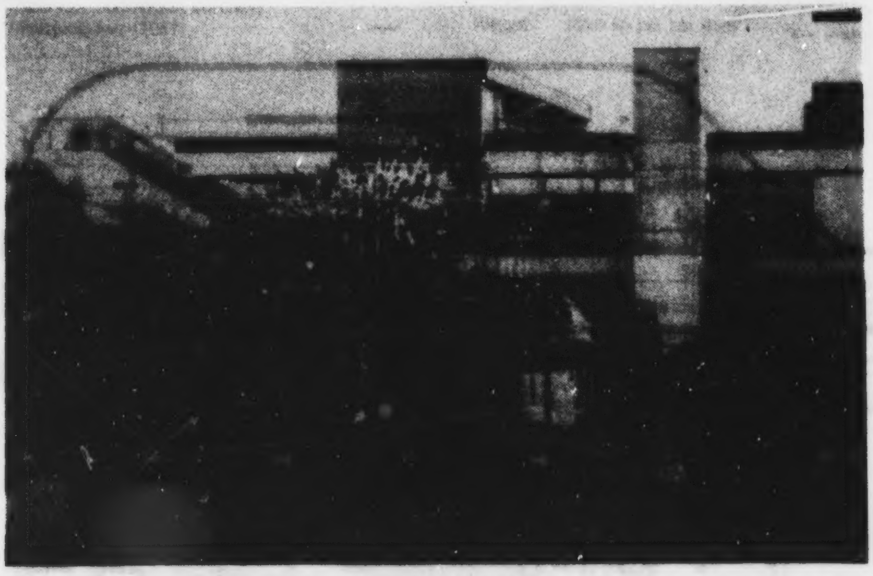


Figure 7.14 T2 WEDway Station: Perspective, Plans, and Section (NORR Airport Planning Associates Ltd.)

Terminal 3

The layout of T3 is assumed to be linear for this study. The T3 station would have the advantage of being totally integrated into the building from the outset, thus improving passenger orientation, circulation, and operational efficiency. The station's platform would be located in the basement level of the centre of the building. Depending on the ultimate size of the new terminal, a second station could be included in a future expansion.

The station in the basement would be at the end of the line. The escalator enclosure would be asymmetrically located in the turnaround area to give maximum clearance at the station doors. If extending the system to the future remote car-park area appears to be realistic at the time of detailed design, a two-sided station at T3 would be required. This would necessitate grouping the escalators at the centre of a wider platform.

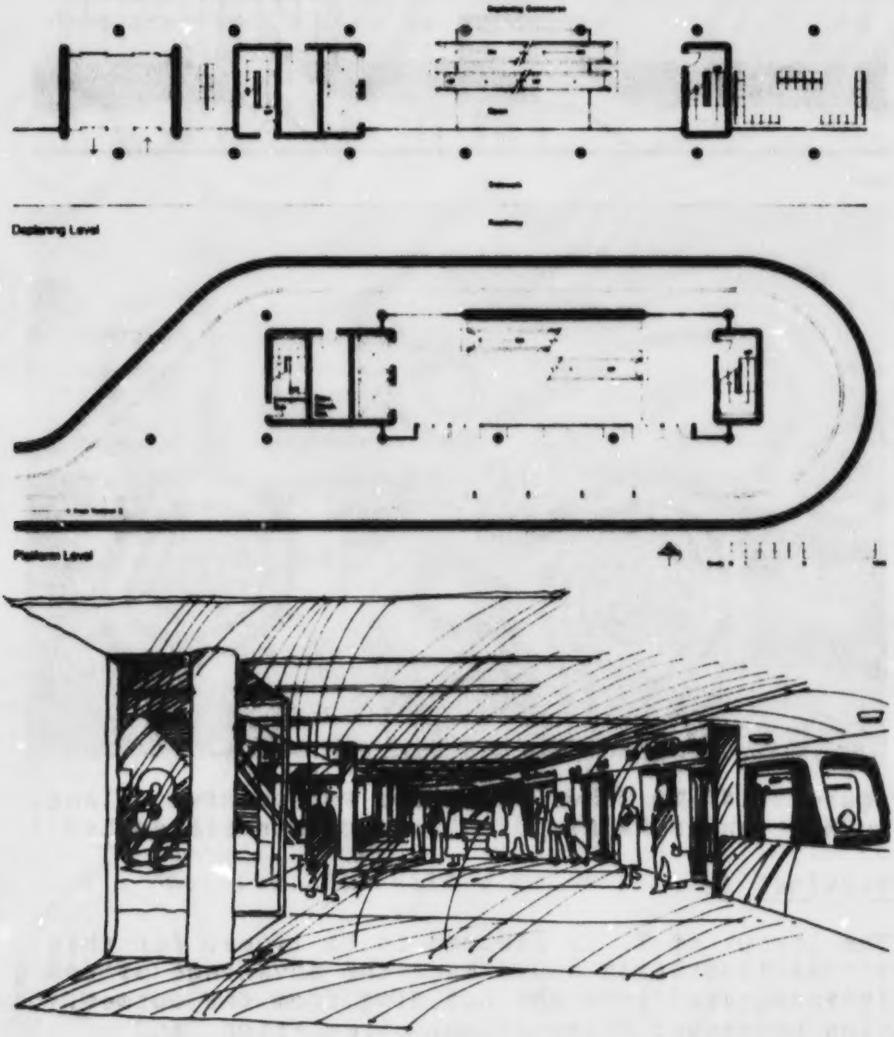


Figure 7.15 T3 WEDway Station: Perspective and Plans (NORR Airport Planning Associates Ltd.)

7.2.3 Design Criteria

General Information:

Comprehensive data on the WEDway system is included in Disney-Turner's report.[2] Pertinent design data are shown in Figure 7.16.

The Houston Airport WEDway PeopleMover (1981)

Vehicle Data

Middle Car Length: 3560 mm

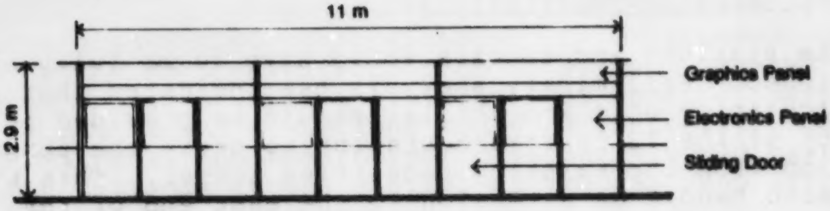
End Car Length: 4140 mm

Separation Distance: 100 mm

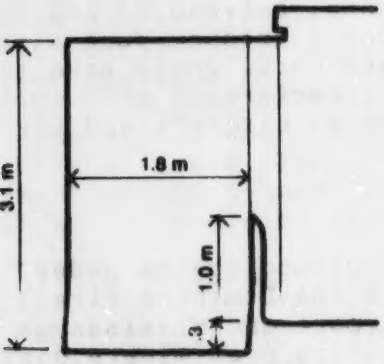
Train Width: 1600 mm at door

Train Height: 2400 mm from guideway floor

Weight: 1950 kg per car (fully loaded)



Typical Station Elevation



Typical Section

Guideway Data

Minimum Guideway Width: 1800 mm

Minimum Guideway Height: 3100 mm

Minimum Turning Radius: 6000 mm to centreline

Figure 7.16 WEDway Design Data

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[2] Intra-Airport Transportation Evaluation, Volume II: Supporting Materials. Disney-Turner, 1982.

Architectural Considerations:

The final station designs would be influenced by the ultimate system route and, in the case of the T3 station, by the planning concept chosen for the terminal itself.

New tunnels would have to have a minimum interior width of 4.8 metres in order to provide a 1.2-metre walkway between the guideways. The minimum tunnel height would be 3.1 metres, but this might vary in certain sections depending on the size of the required mechanical ducts.

Structural Considerations

The dynamic load factors for structural design would be:

Longitudinal:	1.0 gram combined with 1.0 gram down
Lateral:	1.0 gram combined with 1.0 gram down
Vertical:	0.0 gram up, 2.0 grams down

Mechanical Considerations:

The stations and tunnels would have to be fully air-conditioned. Preliminary analysis has indicated that a new air circulation unit and chiller should be provided in the vicinity of the T2 courtyard station to serve the tunnel extension from the existing pedestrian tunnel. This unit would also handle an extension to the east end of the parking garage, should this station prove viable.

To serve the 1,000-metre tunnel between T1 and T3, two air-handling units are recommended to reduce duct sizes and fan capacity. The siting of these units would have to be carefully investigated to avoid interference with current or proposed surface operations, such as aircraft and air cargo traffic.

Fire Safety:

Since this is the only underground system under consideration, close liaison with the Dominion Fire Commissioner's Office and the Airport and Mississauga Fire Departments would be essential during preliminary design stages. The Dominion Fire Commissioner's Office has already raised a number of issues:

i. The station platforms must conform to the National Building Code requirements for a Group A, Division 2 occupancy.

ii. Two exits are required from the platform area. Each would have to achieve at least one half of the total required exit width.

iii. All stations and any tunnel sections located below a building area must have sprinklers. An alternative to installing sprinklers through the entire length of the tunnel between T1 and T3 would be to provide standpipe connections and automatic fire barriers.

iv. Some form of emergency exit must be provided from tunnels. One alternative is to provide escape hatches at 100-metre intervals except where they would exit onto apron areas. Some form of refuge areas may be an acceptable alternative.

7.2.4 Architectural Considerations

Preliminary planning analysis and schematic design indicates that implementation of the WEDway system is physically and operationally feasible, although it would impose significant constraints on the T1 basement planning and on the vertical transportation system. The WEDway system should provide a high level of service, particularly in T1 and T3 where stations would be centrally located. International and transborder passengers would have to walk a long distance to the station at the west end of T2.

Further consideration should be given to the praticality of providing stations at the T2 parking garage and the remote car-park. Deleting the remote car-park station would reduce train length and could result in smaller stations.

The system would have significant impact on certain operational areas, including the T2 service road and the T1 basement and north-west apron area. Careful phasing of the construction could minimize the impact on these operations.

7.2.5 Management Considerations

Walt Disney Productions has designed, manufactured, installed, and operated people-mover systems for over twenty-five years. Turner Construction Company has completed thousands of construction projects around the world in the past eighty years. Disney-Turner offers a comprehensive combination of both talent and experience in addressing TIA's intra-airport transportation requirements. Houston Intercontinental Airport has three terminals linked by an underground WEDway system installed and operated by Disney-Turner.

7.3 Bus Technology

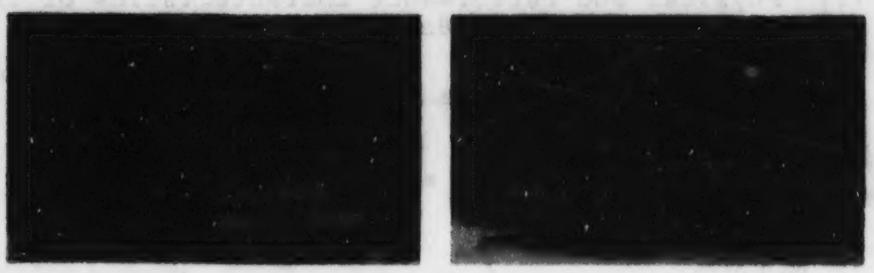
Bus technologies for cities and airports have been developed and refined over many years, and have proven themselves to be flexible and practical. Buses provide low-cost, reliable transportation in a wide range of applications.

Three classes of bus technology are available in North America: small bus, conventional urban bus, and high-capacity bus. A specific vehicle model from each class was chosen for detailed analysis.

Class		Model
Small Bus	-	Orion: 9.5 metres, 31 passengers
Conventional Urban Bus	-	G.M. New Look, 12.2 metres, 53 passengers
High-capacity Bus	-	G.M. Articulated: 18.5 metres, 80 passengers

These models (illustrated in Figure 7.17) represent the realistic range of bus capacities now available for airport shuttle-bus services. The choice of these specific models was based primarily on the availability of operating data. The models provide a reasonable way of both comparing alternative categories of bus technology and comparing bus technologies with other forms of airport shuttle technologies.

Small Bus



Conventional Urban Bus

High-capacity Bus

Figure 7.17 Airport Shuttle-bus Possibilities

7.3.1 General Features and Performance Characteristics

Table 7.1 shows detailed specifications for each of the buses.

7.3.2 System Layout

Technical Working Paper Number 11a analyses the layout and design of several operational bus systems. They range from the use of buses in mixed traffic to progressively preferential treatments, culminating in an exclusive busway along a dedicated right-of-way. The latter concept is examined here because it would have the greatest visual and operational impact on TIA. Figure 7.18 shows the proposed shuttle-bus route for TIA; it appears as Alternative B-4 in Working Paper Number 11a.

Table 7.1 Physical and Performance Characteristics of the Three Buses

Vehicle	Small Bus	Conventional Bus	High Capacity Bus
Manufacturer/Model	Orion	G.M. New Look	G.M. Articulated
Dimensions			
- length (m)	9.5	12.2	18.5
- width (m)	2.5	2.6	2.6
- height (m)	3.0	3.0	3.1
- no. of axles	2	2	3
- curb weight (kg)	8 590	9 409	15 118
Door & Loading			
- door width (m)			
- front	0.96*	0.76*	1.08**
- middle	-	-	1.16**
- rear	0.92*	0.67*	1.16**
- maximum step height (m)	0.33	0.40	0.40
Capacity (no. of seats)			
- standard	31	53	80
- airport application	28	45	70
Mechanical Systems			
- engine	Detroit Diesel Allison	Detroit Diesel Allison	Detroit Diesel Allison
- transmission	Detroit Diesel Allison	Detroit Diesel Allison	Detroit Diesel Allison
Special Features Available			
- kneeling suspension	no	yes (option)	yes (option)
- wheel chair lift	yes (option)	yes (option)	yes (option)
- electronic signing	yes (option)	yes (option)	yes (option)
- radio/avm	yes (option)	yes (option)	yes (option)
- under floor luggage compartment	available	no	no
- air conditioning	yes (option)	yes (option)	yes (option)
Vehicle Performance			
0-50 km/h with maximum load			
- time (sec)	17.5	24.2	***
- acceleration rate (m/sec^2)	0.79	0.57	***
- gradability (%)	5.7	4.1	***
Turning radius (m)			
- min. at 15 km/h	9.6	12.9	13.5
Fuel Consumption (L/km) (standard urban operation)	0.36 - 0.48	0.42 - 0.59	0.59 - 0.91
Canadian Content			
- % parts manufacture	60	60	60
- % assembly	100	100	100
Capital Cost (1981 dollars)	95,000	130,000	300,000
Vehicle O & M Cost (1981 dollars per km)			
- fuel, oil & maintenance	0.30	0.33	0.38

* Single ** Double *** Not available

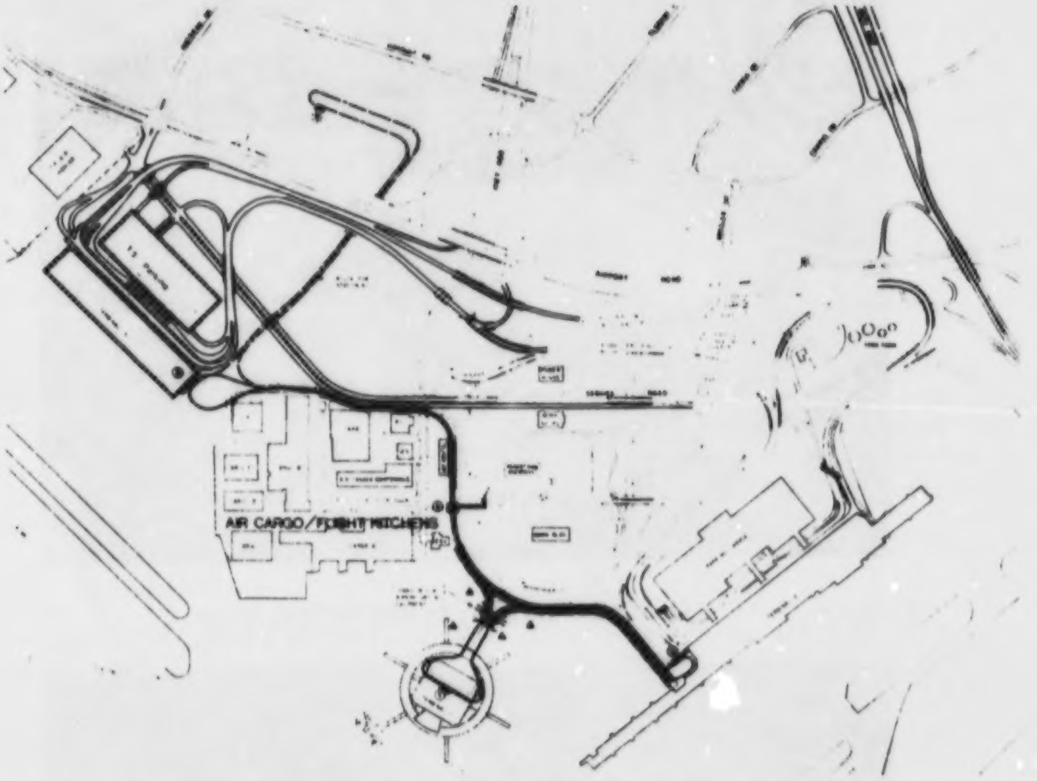


Figure 7.18 Proposed Shuttle-bus Route

7.3.3 Facilities Impact and Architectural Considerations

Terminal 1

Buses would continue to use the T1 enplaning curb, which would be connected to the apron roadway by a set of new ramps. Apron security would be provided by automatic gates in one of two formats. Figures 7.19 and 7.20 illustrate one option: the shuttle bus would have priority and apron vehicles would activate the automatic gates. This option would be justified if the movement of apron traffic was limited and infrequent. Further consideration should be given to a second option in which apron vehicles would have the right-of-way and the gates would be relocated so they could be activated by the buses. (This option is not illustrated.)

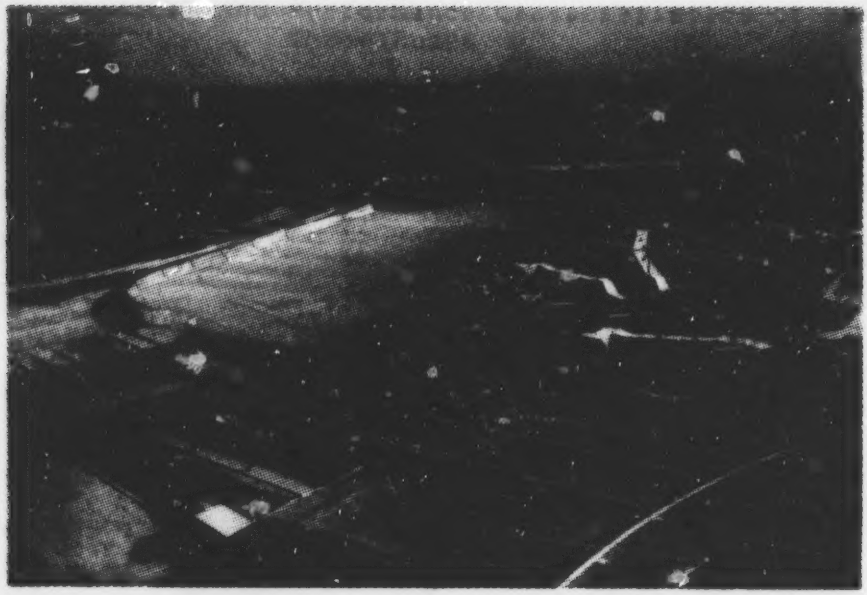


Figure 7.19 Shuttle-bus System: View from T1 to T2

Figure 7.20 Shuttle-bus System: View from T1 to Cargo Area

Terminal 2

The route would loop around the west end of T2 within the area presently occupied by a parkette. From the standpoint of passenger orientation, comfort, and circulation, the most appropriate access to the station would be through the west end of the arrivals concourse. Since existing washrooms and escalators in this area do not permit additional seating for waiting passengers, the concourse should be extended to the west. The new station (Figure 7.21) would provide a waiting area, a vestibule, and an exterior canopy. Judicious use of glazing would allow the arrivals and the departures concourses to retain their natural light and views.

The median area formed by the bus loop would become a landscaped courtyard.

Terminal 3

Access to the proposed transit stop for T3 would be from the end of the public concourse. Figure 7.22 shows a possible station layout in a hypothetical T3 configuration. These drawings assume that the station would be located on the ground level rather than on an elevated busway.

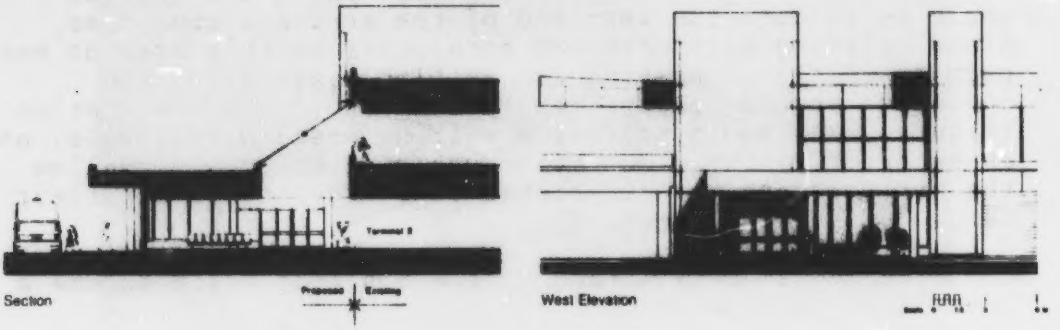
Cargo Area

Bus stops adjacent to the Ring Road east of the air cargo area would be provided for employees travelling to T3 or the remote car-park, and for passengers using the reduced rate car-park north of the administration building. Standard, prefabricated bus shelters would be installed there.

A pedestrian overpass would allow users to safely cross the Ring Road.

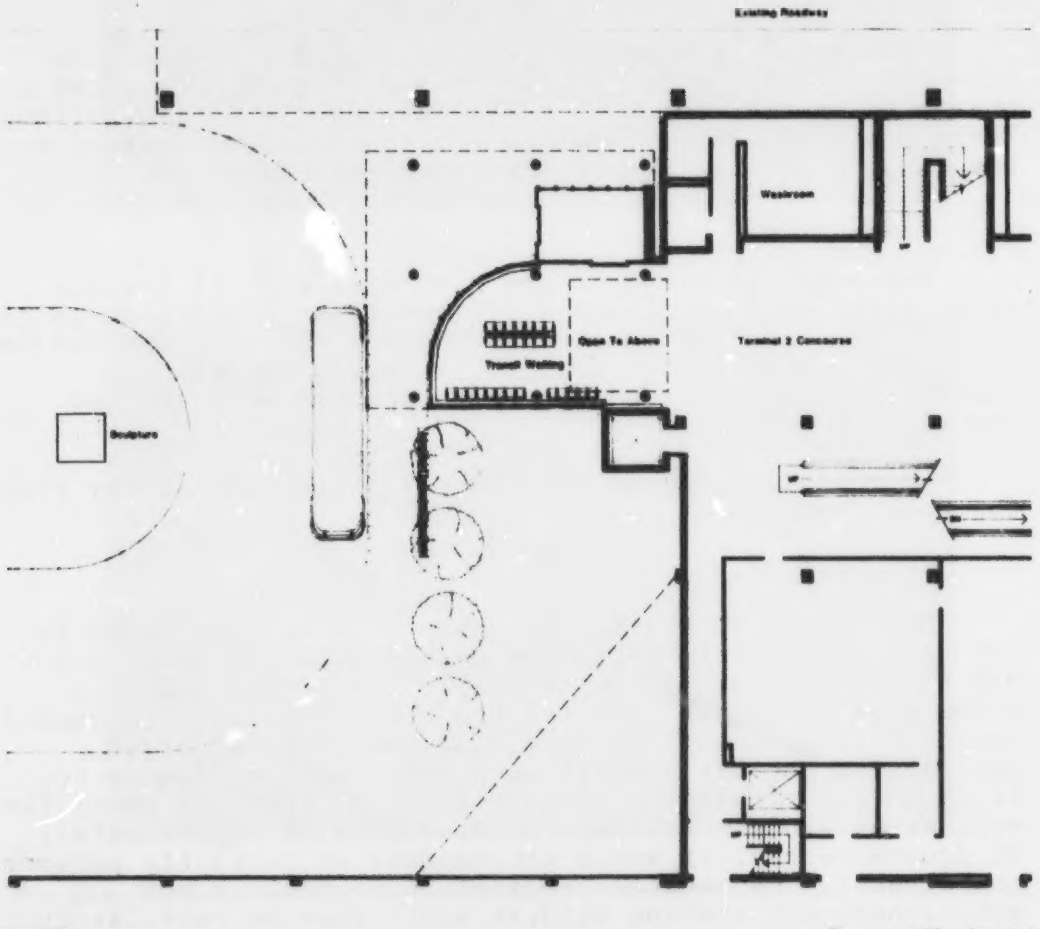
Remote Parking

Two bus station alternatives should be considered for the remote car-park, depending on its size and arrangement. The first option would be several standard bus shelters along a major access road through the car-park. The second option, illustrated in Figure 7.23, would be a larger, centralized shelter located on a landscaped median strip. It would be oriented to provide a buffer from the prevailing north-west winds. With an enclosed area of approximately 60 square metres, it would accommodate up to thirty persons comfortably. Mechanical temperature control is not envisioned, but opening windows would provide ventilation during the summer. Natural light from the peak skylight would be supplemented by fluorescent fixtures. A canopy would provide protection from the weather while embarking or disembarking. The siting and bold design of this facility


Terminal 2
Proposed
Existing
Scale

Section

West Elevation


Existing Roadway
Washroom
Open To Above
Transit Waiting
Terminal 2 Concourse
Sculpture
Scale

Floor Plan

Figure 7.21 T2 Shuttle-bus Station: Section Elevation and Floor Plan (NORR Airport Planning Associates Ltd.)

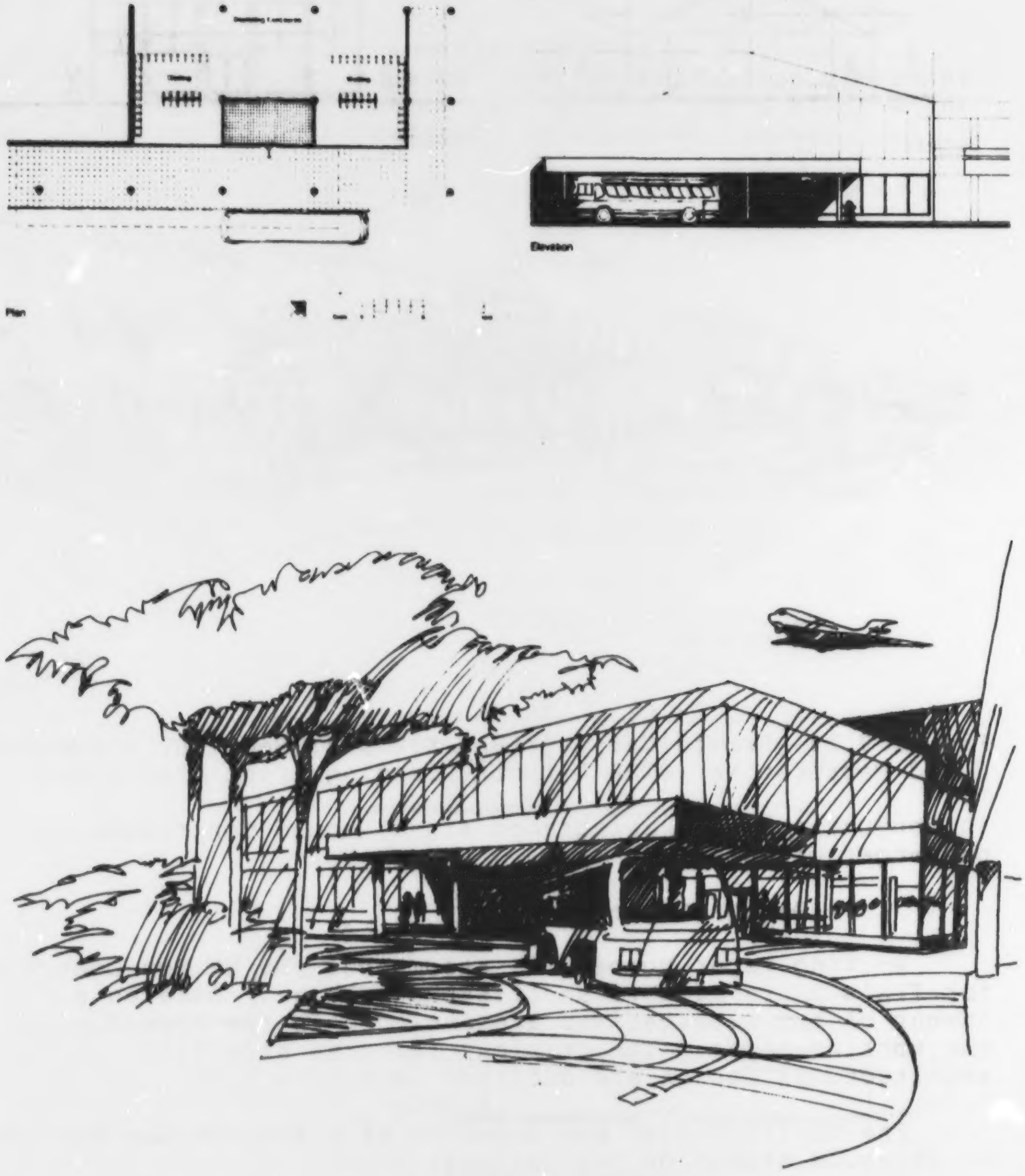
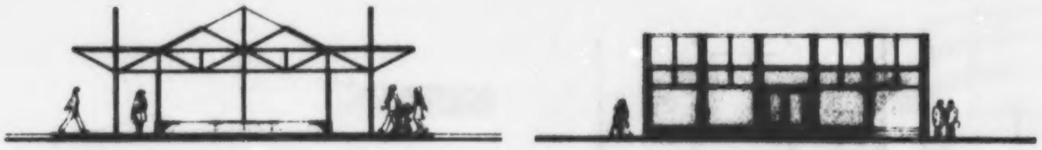

Elevation
Plan

Figure 7.22 T3 Shuttle-bus Station: Elevation, Floor Plan, and Perspective (NORR Airport Planning Associates Ltd.)



Section

Elevation

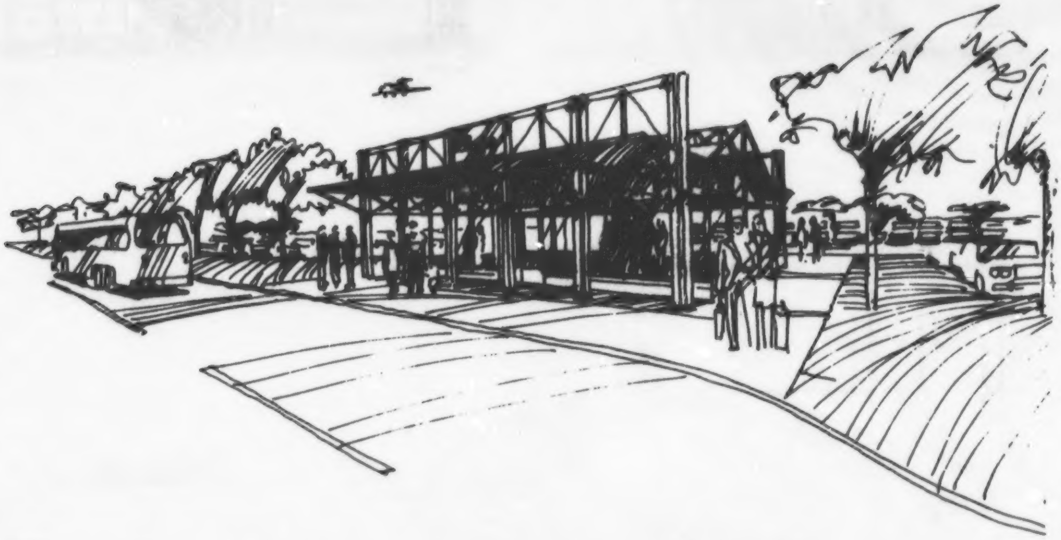


Figure 7.23 Remote Car-park Bus Station: Section, Elevation, and Perspective (NORR Airport Planning Associates Ltd.)

in conjunction with integrated signs, would contribute to passenger orientation.

7.3.4 Design Criteria

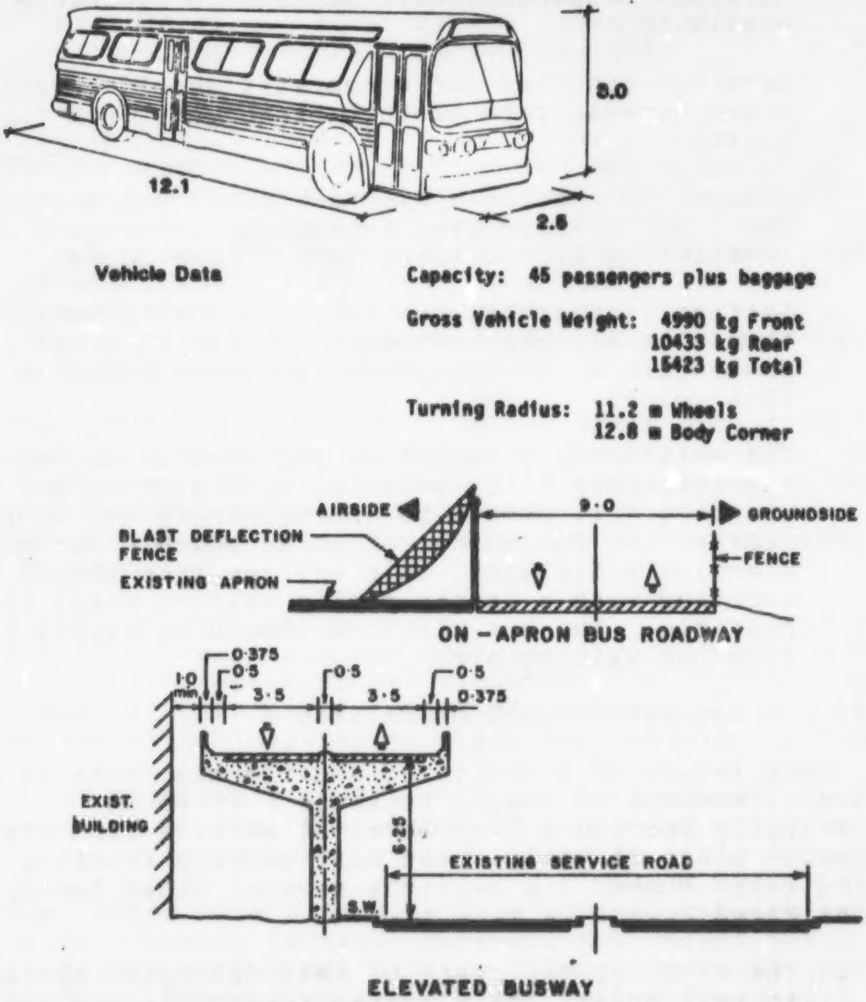
Working Paper Number 11a recommends the GM New Look Bus for TIA's intra-airport shuttle-bus service. Data on a number of bus alternatives are included in the appendix to the working paper. The critical features affecting architectural design are outlined in Figure 7.24.

The configuration and location of a shuttle-bus station in T3 would depend on two factors:

- The final planning concept of T3, including groundside access.
- The shuttle-bus route. From a phasing standpoint, it might be preferrable to design T3's road system and concourse to accommodate both a dedicated roadway and shared use of internal roads.

General design criteria which should be considered for the T3 station include:

- Location: The shuttle-bus station must be conveniently located to minimize walking distances. Depending on the concept for T3, the station might have to be accessed by an elevated roadway.


8.0
12.1
2.6
AIRSIDE
BLAST DEFLECTION FENCE
EXISTING APRON
9·0
GROUNDSIDE
FENCE
0·375
1·0 min.
0·5
3·5
0·5
3·5
0·5
0·375
EXIST. BUILDING
6·23
EXISTING SERVICE ROAD
S.W.

Vehicle Data

Capacity: 45 passengers plus baggage

Gross Vehicle Weight: 4990 kg Front
10433 kg Rear
15423 kg Total

Turning Radius: 11.2 m Wheels
12.8 m Body Corner

ON - APRON BUS ROADWAY

ELEVATED BUSWAY

NOTES: (1) DIMENSIONS ARE IN METRES.
(2) VERTICAL SCALE IS EXAGGERATED FOR CLARITY.

Figure 7.24 Shuttle-bus Design Data (DeLCan)

- Curb length: It must be at least 32 metres long to accommodate two buses simultaneously, one heading to the remote car-park and the other to the other terminals. The positions of the buses should be graphically identified to assist passenger orientation. Waiting positions for additional buses could be provided off-curb.

- Sidewalk width: It must be at least 4 metres wide to allow passengers with baggage to circulate easily.

- Generous canopies and windbreaks should be built where necessary to protect passengers from the weather.

- A generous vestibule with automatic doors should be provided to allow easy access for passengers while restricting air movement through the doors.

- Vertical transportation to other public levels should be visible upon entering the terminal. Many passengers would require orientation graphics at this point.

- The waiting area should be designed to accommodate approximately fifty persons, both sitting and standing. It should be approximately 100 square metres, not including concourse space. For maximum planning efficiency, this waiting area should be combined with a larger public waiting area, if possible. The bus platform should be easily visible from the waiting area.

7.3.5 Architectural Considerations

Installation of a dedicated shuttle-bus route is both physically and operationally feasible. It would theoretically provide a high level of service from station to station since it would avoid most surface traffic. Working Paper Number 11a mentions several other factors to be considered:

- The high capital costs of this dedicated system -- in particular, the elevated roadway around the cargo area -- must be weighed against lower-cost alternative routes using the internal road system.

- The buses must continue to use the T1 departures roadway with its inherent limitations. The operational implications of crossing the apron are significant and must be investigated in greater detail.
- The bus station located at the west end of T2 is not convenient for international and transborder passengers due to the walking distances involved. If the shuttle bus is selected, the design of T3 must carefully consider the integration of a conveniently accessible bus station.

7.3.6 Management Considerations

The management of the shuttle-bus operation must reflect the overall scale of operation. For operations with approximately twenty buses or less, it is suggested that TIA own the buses and the premises for maintenance and storage, and contract out the operation. The contractor would provide qualified drivers, mechanics, and supervisory personnel to ensure that a specified level and quality of service is provided each day.

The number of staff required and their qualifications would depend greatly on the scale of operation. The table below indicates the average number of employees per bus now employed in urban transit operations in Canada. This provides an indication of the total number of employees that would be required.

Number of properties[3]	33
Number of operators per vehicle	1.49
Number of inspectors per vehicle	.07
Number of maintenance staff per vehicle	.64
Number of administrative staff per vehicle	.36

Due to the relatively small scale of the proposed shuttle-bus operation at TIA, the number of employees required per vehicle could be somewhat greater than the table suggests.

Most buses have a service life of twelve years, at minimum maintenance levels. However, the recent trend has been to try to extend the service life of buses by improving maintenance. Rebuilding a bus after twelve years will often extend its service life to eighteen years, and at a lower cost than purchasing a new bus. Assuming an average service life of fifteen years will provide a reasonable basis on which to plan the shuttle-bus service. However, the specific bus used and the economic conditions existing when the service is provided will determine service life. In the interests of preserving a positive image, a policy similar to that of the New York Port Authority, which replaces buses after only seven years, might also be considered.

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[3]. Source: Canadian Urban Transit Association, 1979 Statistics.

8. DETAILED EVALUATION OF THE THREE ALTERNATIVES

Chapter 5 used a limited but critical set of criteria to select thirty technology alternatives. Chapter 6 evaluated these alternatives using seven upper-tier goals. This reduced the list to three kinds of technologies which promised to be the most cost-effective for TIA: (1) an intermediate capacity elevated guideway (ICTS or Westinghouse Transit Expressway); (2) a light tunnelled guideway (WEDway); and (3) a shuttle-bus system. Chapter 7 described how these technologies could be applied at TIA using currently available products. This chapter provides a comparative evaluation of the three alternatives. Technical Working Paper Number 14 contains detailed results of the evaluation, as well as recommendations and conclusions about the intra-airport transportation needs of TIA to the year 2000 and beyond.

8.1 Decision Tree

Several of the criteria used in this detailed evaluation depend on the travel demand placed on the system. The size and configuration of the system in turn affect its cost, energy consumption, and environmental impact. In other words: the greater the demand on the system, the higher its cost, energy consumption, and environmental impact. This evaluation sets out the transportation implications of a wide range of possible development options for TIA, all of which lead to different demand patterns.

Figure 8.1 shows a simplified decision tree of the short-range and medium-range development options open to the airport which will influence demand. These decisions include, reading from left to right:

- Will T3 be constructed in the short to medium run? It is assumed that if T3 is constructed, it will include a parking garage for users (Pu) and employees (Pe).
- How will the airlines be allocated between the terminals? Will they be allocated according to Transport Canada preferred strategy (S4), or according to the airlines' preferred plan (AP)? If T3 is not constructed, will allocation remain as it is now, or will the situation be rationalized by shifting traffic from T1 to T2?

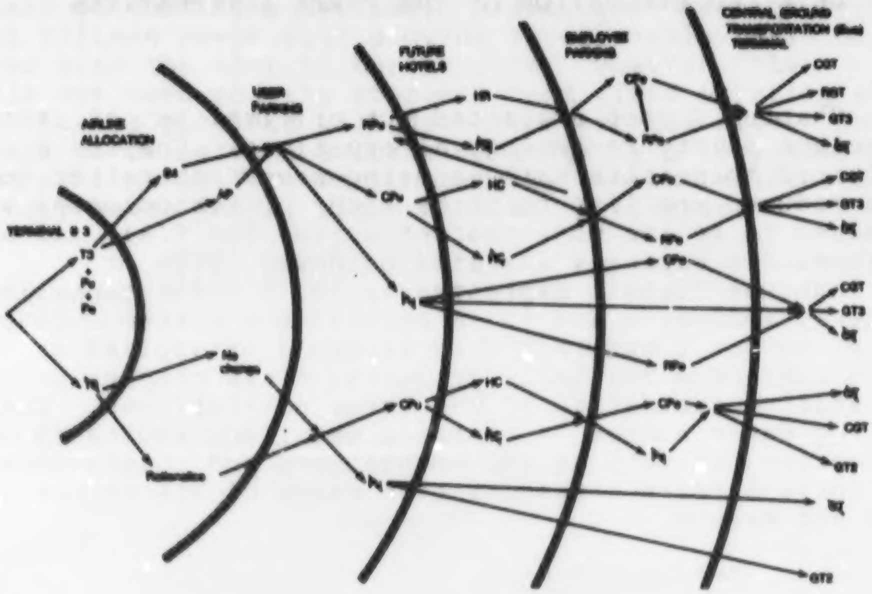
CENTRAL GROUND TRANSPORTATION (Bus) TERMINAL
EMPLOYEE PARKING
FUTURE HOTELS
USER PARKING
AIRLINE ALLOCATION
TERMINAL # 3
T3
No change
Rationalize
RPu
CPu
HR
HC
CPe
RPe
CGT
RGT
GT3
GT2

Figure 8.1 TIA Decision Tree

- Will additional user parking facilities be constructed? If so, will a car-park be constructed in the remote land owned by Transport Canada north of Airport Road (RPu), or will a garage be constructed behind the administration building (CPu)?
- Will a hotel be constructed? If so, will it be constructed as part of the land development north of Airport Road (HR), or will it be constructed behind the administration building (HC)?
- If T3 is constructed, where will the employee car-park which it displaces be relocated: north of Airport Road (RPe) or in a central location behind the administration building (CPE)? If T3 is not constructed, will new employee parking be provided?
- Will a central bus terminal be constructed? If so, where will it be located: remotely across Airport Road (RGT) as part of the T3 development (GT3), at the central site behind the administration building (GTC), or at T2 (GT2)?

Once a path through this decision tree is established, the peak (design) demand on the system can be determined and the system laid out and sized to serve the demand at the desired level of service. The cost, energy consumption, and environmental impact can be determined from the layout distances, number of vehicles, headways, etc. The latter are functions of the specific technology, vehicle kilometres of service, hours of service, etc.

Energy consumption and environmental impact are also functions of demand. However, they are less critical to the decision process than is the cost. For this reason, they are not treated separately, as is cost, but are included with the other non-demand, dependent criteria in the multi-criterion evaluation.

8.1.1 Constraints

A major constraint affecting choice of one of the technologies is their maximum passenger capacity. This is particularly acute in the case of the shuttle bus, where curb occupancy limitations impose a practical minimum headway of two minutes. This means a shuttle-bus system could carry a maximum of approximately 1,500 passengers an hour. Many of the possible paths through the decision tree result in demands well in excess of this figure. Therefore, the peak and annual demand forecasts generated by the decision tree can be used to reduce the number of technology alternatives, by identifying those with insufficient capacity to cope with the peak demand. To help analyse the relationship between demand and capacity for each technology for different development scenarios, a computer program has been written as part of this evaluation. It allows the program user to specify the development pattern for the airport and then determine the peak link volumes for each year. This in turn can be used to determine at what point each of the technologies will reach capacity (if ever). This computer program allows the analyst to consider developing a transportation system in stages, that is, starting with buses then converting to a higher technology option when the bus system reaches capacity. It also allows the analyst to examine the impact of such policies as not carrying employees.

Capacity is not the only choice constraint. Three others are:

- The light tunnelled guideway cannot be used if service must be provided to the area behind the administration building (all branches marked "C" in the decision tree). The light tunnelled guideway cannot reasonably be made to service this area because it is impossible, from a civil engineering viewpoint, to dig a tunnel to this location.

- The shuttle-bus system cannot be used with a central bus terminal (all branches marked GT). From a service perspective it is unreasonable to expect users to transfer from one bus to another on a short trip.

- If peak demand is below 1,000 passengers an hour, the intermediate capacity elevated guideway represents "technological overkill" and need not be seriously considered further.

Figure 8.2 illustrates how these choice constraints can be combined with a chosen path through the decision tree to reduce the number of technology alternatives for TIA.

8.1.2 Costs

Cost is the most important criterion. Since there are so many possible paths through the decision tree, and since life-cycle costs are possible, the computer program has been extended to permit analysis of the time stream of costs (i.e., life-cycle costs) associated with each alternative. The analyst is free to specify:

a) the desired land-use development pattern for TIA;
b) the forecast growth rate for air traffic;
c) the discount rate for funds.

From this input, the known operating and capital costs of each of the technologies, the equivalent annual cost, and the net present worth of each alternative can be computed over an assumed thirty-year service life for the system. The computer program also divides the equivalent annual cost by the annual number of users to calculate the cost per passenger. This indicates the revenue which would have to be collected from each passenger to make the system self-supporting. Figure 8.2 illustrates how this information flows from the decision tree.

If the transportation system is developed in stages, from shuttle bus to the intermediate capacity elevated guideway or the light tunnelled guideway, there will be a significant increase in the life-cycle costs. The key decision (when a decision is possible) is this: Do the increased advantages of the higher technologies outweigh their increased cost? In other words, what does TIA buy with the increment?

8.1.3 Staging

The technology alternatives are not mutually exclusive. It may be possible, and even desirable, to stage development by starting with, for example, shuttle buses and only converting to a higher technology when demand levels begin taxing the bus system's capability. The computer program has been designed to consider staging. The end state of the system must be determined in considering staging, as this could have a profound impact on short-term and mid-term decisions. For example, if staged growth from buses to a guideway system is chosen, provisions should be made to accommodate a guideway station and, possibly, a maintenance facility in the plans for T3 or a central parking facility. Such contingency planning will pay large dividends in the future by keeeping rights of way open and reducing the cost of retrofitting facilities.

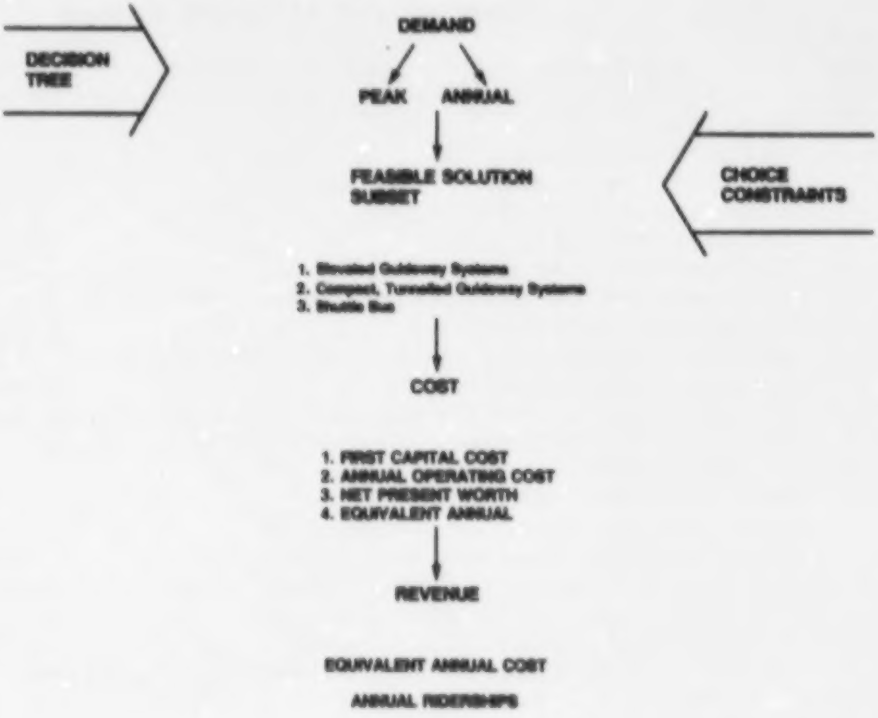
DECISION TREE
DEMAND
PEAK
ANNUAL
FEASIBLE SOLUTION SUBSET
CHOICE CONSTRAINTS
1. Elevated Guideway Systems
2. Compact, Tunnelled Guideway Systems
3. Shuttle Bus
COST
1. FIRST CAPITAL COST
2. ANNUAL OPERATING COST
3. NET PRESENT WORTH
4. EQUIVALENT ANNUAL
REVENUE
EQUIVALENT ANNUAL COST
ANNUAL RIDERSHIPS

Figure 8.2 Choice Constraints

8.2 Impact Group Evaluation Criteria

The project team recognized over two hundred groups and several hundred individuals who would be interested in, or affected by, major changes at TIA. Of these, nineteen groups who would be directly affected by changes to the intra-airport transportation system were selected. These are listed in Table 8.1. The nineteen groups were collapsed into six impact groups. Their representation in the survey is shown in Table 8.2.

Table 8.3 shows the original study criteria and how these were revised to survey these six groups.

All respondents answered the questionnaire as individuals. Some individuals also met in groups to complete the questionnaire and then, following its completion, participated in focus group interviews.

Results and analyses of the evaluation of the respondent groups' criteria are contained in Technical Working Paper Number 12 and incorporated in Section 8.4 of this report.

Table 8.1 Interested and Affected Groups

GROUPS

Airlines
Airport Employees
Aviation Services
Brampton Board of Trade
Cargo Industry
Concessionaires
Engineering Co-ordination Committee
Federal Government
General Aviation
Ground Transportation
Hotel Association (proxy for the travelling public)
Members of Parliament/Members of Provincial Parliament
Metro Toronto Council
Mississauga Board of Trade
Peel Council
Private Aircraft Owners
Toronto Board of Trade
Transport Canada
Urban Transportation Co-ordination Committee

8.3 Multi-criterion Analysis

A multi-criterion evaluation procedure has been adopted to take account of the many factors involved in chosing an intra-airport transportation system. This report does not present a single conclusion. Rather, it should be used as a decision-making tool to evaluate the ground transportation implications of a wide range of development options for TIA. One important limitation of this tool is that while it considers the impact of a transportation system on users it does not examine its impact on non-users, which is potentially of equal importance. This limitation is due to the fact that the 1980 survey data and updated Groundside

Travel Demand Model were not received from the consultants preparing them in time to be included. Without this information it is not possible to analyse the full impact of airport development options. Improvements in traffic flow and greatly reduced traffic delays could be used to justify a greater investment in the intra-airport transportation system. Decision-makers are cautioned that this key element is missing. Decisions should not be made without obtaining the traffic impact data from the revised Groundside Travel Demand Model.

Table 8.2 Impact Groups, Associated Interested and Affected Groups, and Representatives Surveyed

Impact Group	Interested and Affected Groups	Survey Representatives	Number of Persons Surveyed
Air Service Operators	Airlines Concessionaires	Airline Operator's Committee	1
		Cara	1
		Car Rentals	3
		Travellers Aid	2
Ground Transport Operators	Ground Transportation	Limousine Operators Association	2
		Airport Taxi Operators Association	
		Airport Public Vehicle Operators Association	2
Airport Employees	Airport Employees	Airport Employees (Sample)	13
Users	Toronto Board of Trade	Toronto Board of Trade	2
	Travelling Public	Travelling Public (Sample)	17
Government	Urban Transportation Co-ordination Committee	Urban Transportation Co-ordination Committee	12
	Engineering Co-ordination Committee	Engineering Co-ordination Committee	8
Airport Operators	Transport Canada	TAO	1
	Federal Government	ORA	1
		DGK	1
		DGAP	1

Unlike the preliminary evaluation carried out in Chapter 6, which used seven upper-tier goals to compare thirty technology alternatives, this final, detailed evaluation uses an expanded list of goals and objectives to compare the three shortlisted technologies. They include those used in the preliminary evaluation, shown in Table 8.4 on the left, and those which have been added for this final evaluation, shown on the right.

Table 8.3 Evaluation Criteria: Original and Revised

ORIGINAL	REVISED
Convenient Transfer Accessibility	Ease of Use: - Convenient Transfer - Accessibility - Luggage Handling - Comprehensibility - Comfort
Reliability	Reliability
Flexibility	Flexibility
Ease of Implementation	Ease of Implementation: - Compatibility With Plans - Compatibility With Operations - Equity of Treatment - Energy Conservation - Economical Development Factors
Environmental Impact	Environmental Impact: - Pollution Factors - Quality of Life Enhancement
	Safety and Security
Cost	

This final evaluation is more refined than the preliminary evaluation. The latter used simple, qualitative statements of comparison or approximate ranges of data, while this evaluation uses detailed, accurate, quantitative measures of comparison. This reveals the absolute merits of the technologies as well as their relative merits.

Table 8.4 Evaluation Criteria

Class	No.	Primary Criteria	No.	Secondary Criteria
Transportation	1	Convenience	4	Compatibility with Other Plan
	2	Accessibility	5	Compatibility with Air Operations
	3	Reliability	6	Luggage and Cargo Handling
			7	Comfort
Finance	8	Cost	10	Revenue
	9	Flexibility	11	Energy
			12	Industrial Development
Social	13	Ease of Implementation	14	Safety and Security
			15	Equity
Environment	16	Clean, Healthy Environment	17	Quality of Life

Many of the criteria cannot be reduced to purely economic terms. It is therefore necessary to perform a multi-criterion evaluation. In other words, the final decision will not be dictated by a single factor (e.g., minimum total cost), but will require trade-offs between the alternatives. This evaluation quantifies, to the maximum extent possible, these trade-offs and points out the critical issues involved in making a final decision. This evaluation report serves as a decision-making tool. It allows maximum flexibility in analysing the wide range of potential development scenarios for TIA.

8.4 Summary of Evaluation Results

Table 8.5 ranks each of three technology alternatives on each of the the eighteen, non-demand-dependent criteria. Table 8.6 shows which technology was most often ranked first. Together these two tables indicate that each of the three technologies have definite strengths and no one technology is best from the non-economic perspective (i.e., level of service, ease of implementation, etc.).

Relative Scores

Table 8.7 shows the rank scoring for each technology on a relative scale of 0 to 10. A score of 10 represents outstanding performance, while a score of 0 represents unacceptable performance. Once again, it is evident that each of the three technologies have definite strengths and no one technology is best from the non-economic perspective.

Table 8.5 How the Technologies Rank

	1st	2nd	3rd
1. CONVENIENCE	ICEG	LTG	SB
2. ACCESSIBILITY	ICEG	SB	LTG
3. RELIABILITY	LTG	SB	ICEG
4. COMPATIBILITY W/PLANS	ICEG	SB	LTG
5. COMPATIBILITY W/AIR	LTG	SB	ICEG
6. COMPREHENSIBILITY	ICEG	LTG	SB
7. LUGGAGE AND CARGO	ICEG	LTG	SB
8. COMFORT	LTG	ICEG	SB
9. COST			
10. FLEXIBILITY	SB	ICEG	LTG
11. REVENUE (COST/PASS.)			
12. ENERGY	SB	LTG	ICEG
13. INDUSTRIAL DEVELOPMENT	ICEG	SB	LTG
14. EASE OF IMPLEMENTATION	SB	ICEG	LTG
15. SAFETY AND SECURITY	LTG	ICEG	SB
16. EQUITY	ICEG	LTG	SB
17. ENVIRONMENT	LTG	ICEG	SB
18. QUALITY OF LIFE	LTG	ICEG	SB

Note: ICEG = Intermediate Capacity Elevated Guideway
LTG = Light Tunnelled Guideway
SB = Shuttle Bus

Table 8.6 Best Performers or Each Criterion

	ICEG	LTG	SB
1. CONVENIENCE	X		
2. ACCESSIBILITY	X		
3. RELIABILITY		X	
4. COMPATIBILITY W/PLANS	X		
5. COMPATIBILITY W/AIR		X	
6. COMPREHENSIBILITY	X		
7. LUGGAGE AND CARGO	X		
8. COMFORT		X	
9. COST			
10. FLEXIBILITY			X
11. REVENUE (COST/PASS.)			
12. ENERGY			X
13. INDUSTRIAL DEVELOPMENT	X		
14. EASE OF IMPLEMENTATION			X
15. SAFETY AND SECURITY		X	
16. EQUITY	X		
17. ENVIRONMENT		X	
18. QUALITY OF LIFE		X	

Table 8.7 Rank Scoring by Technology (0-10)

	Elevated Guideway Systems	Light, Tunnelled Guideway Systems	Shuttle Bus
1. CONVENIENCE	10	9	3
2. ACCESSIBILITY	9	3	7
3. RELIABILITY	4	9	7
4. COMPATIBILITY W/PLANS	9	3	8
5. COMPATIBILITY W/AIR	3	10	4
6. COMPREHENSIBILITY	9	6	3
7. LUGGAGE AND CARGO	9	6	2
8. COMFORT	9	10	2
9. COST			
10. FLEXIBILITY	2	2	9
11. REVENUE (COST/PASS.)			
12. ENERGY	5	5	6
13. INDUSTRIAL DEVELOPMENT	10	2	3
14. EASE OF IMPLEMENTATION	3	2	9
15. SAFETY AND SECURITY	9	10	5
16. EQUITY	10	9	2
17. ENVIRONMENT	8	10	2
18. QUALITY OF LIFE	8	10	4

Weighted Comparison

All crtieria do not have equal weight. Therefore, while each is relevant, they do not influence the decision process equally. Moreover, the weight placed on each criterion depends upon the perspective of the groups assessing the alternatives. For example, users would place a higher premium on convenience than would the system operator, while the operator would place a higher premium on flexibility, which would not interest users at all.

In recognition of these differences, a weighted comparative evaluation was carried out. Because it is difficult to assign meaningful weights to so many criteria, the process was divided into two stages. First, the criteria were grouped under general categories and their relative contribution to the importance of each category was assessed. Figure 8.3 shows the results of this assessment, presented in full in Technical Working Paper Number 14. Second, the relative importance of each general category in choosing a system was assessed from the perspective of each impact group. Table 8.8 presents this breakdown. The importance of each criterion was determined by: multiplying the weighting assigned to the criterion within the general category by the weighting assigned to that general category by the impact group under consideration. For example, the importance of convenience from the point of view of users is: 0.4 X 0.5 = 0.2.

Table 8.9 shows the results of this weighted comparison. The users, employees, and airlines favour the intermediate capacity elevated guideway and the light tunnelled guideway, not suprisingly, because they offer a high level of service. Transport Canada, again not surprisingly, favours the shuttle bus, with its ease of implementation and much greater flexibility.

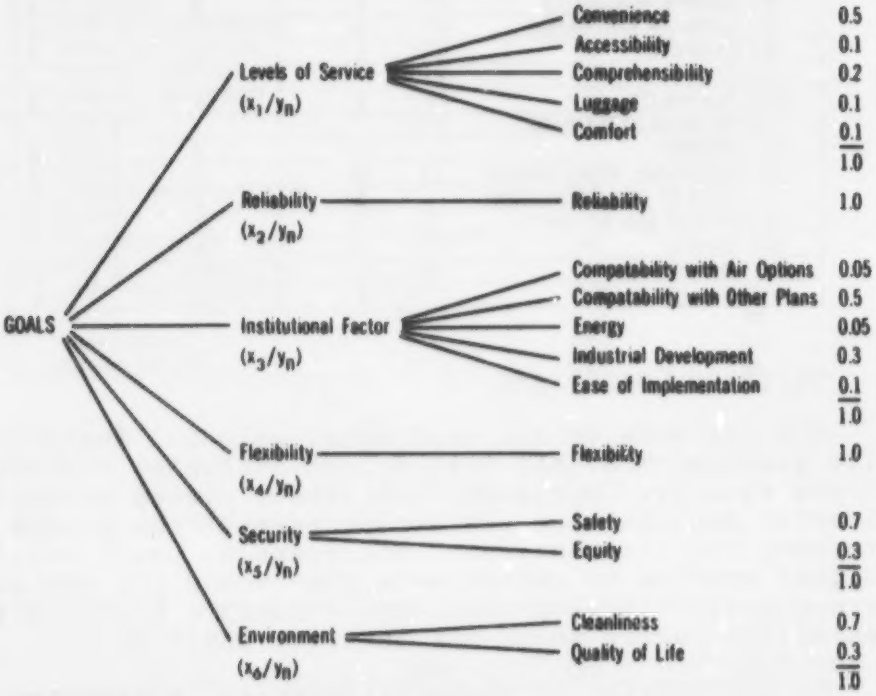
GOALS
Levels of Service
(x_1/y_n)
Convenience 0.5
Accessibility 0.1
Comprehensibility 0.2
Luggage 0.1
Comfort 0.1
1.0
Reliability
(x_2/y_n)
Reliability 1.0
Institutional Factor
(x_3/y_n)
Compatability with Air Options 0.05
Compatability with Other Plans 0.5
Energy 0.05
Industrial Development 0.3
Ease of Implementation 0.1
1.0
Flexibility
(x_4/y_n)
Flexibility 1.0
Security
(x_5/y_n)
Safety 0.7
Equity 0.3
1.0
Environment
(x_6/y_n)
Cleanliness 0.7
Quality of Life 0.3
1.0

Figure 8.3 Relative Contribution of Each Criterion

Table 8.8 Impact Group Assessment

		IMPACT GROUP					
		USERS	EMPLOYEES	AIRPORT OPERATOR	AIRLINES	BUS/TAXI	PUBLIC
ALTERNATIVES	Elevated Guideway Systems	7.06	7.11	5.87	5.63	6.47	6.39
	Light, Tunnelled Guideway Systems	8.68	8.82	5.22	7.49	6.30	5.48
	Shuttle Bus	4.46	4.84	8.47	5.91	5.77	5.78

The weighted comparison can be carried one step further: the importance of each impact group to the decision process can be assessed and their scores for each option weighted by this importance factor. The results are shown in column "d" in Table 8.9. The two guideway systems are favoured and the light tunnelled guideway has a slight advantage. If the weight assigned to Transport Canada is increased relative to the other impact groups from 0.4 to 0.7, there is little or no difference between the technologies, from the non-economic perspective, and the decision is reduced primarily to a question of cost.

Weighting the criteria and impact groups does not reveal a clearly preferred technology. It does, however, sharpen the focus on the key trade-off. This is between, on the one hand, the level of service advantages offered by the two guideway systems to users, and, on the other hand, the cost, inflexibility, and difficulty of implementing these two systems as seen by Transport Canada.

Table 8.9 Four Schemes to Assign Weighting of Impact Groups

IMPACT GROUP	WEIGHTING SCHEME			
	a	b	c	d
USERS	0.3	0.25	0.2	0.2
EMPLOYEES	0.1	0.1	0.05	0.05
MANAGEMENT	0.4	0.5	0.6	0.7
AIRLINES	0.1	0.1	0.1	0.05
BUS/TAXI	0.05	0	0	0
PUBLIC	0.05	0.05	0.05	0

8.5 Critical Trade-offs

While all of the criteria are important, they are so many and so diverse that it is difficult to focus on the critical trade-offs which must be made in selecting an intra-airport transportation system for TIA. Some criteria have only marginal importance. Others, though unquestionably important, are attained equally by all three technologies and therefore can safely be removed from further consideration; they will be realized whatever technology is chosen. Removing both of these classes of criteria produces the ranking shown in Table 8.10.

Before choosing a technology, decision-makers must answer this question: Do the advantages of the two guideway systems -- convenience, achievement of the airport master plan, and support of Canadian industrial development -- justify (1) the greater difficulties involved in implementing these systems compared with the shuttle-bus system; (2) their greater cost; and (3) the risk that the need for such a high-capacity system may never materialize?

Table 8.10 Simplified Analysis (X = First)

CRITERIA	ICEG	LTG	SHUTTLE BUS
Convenience and Accessibility	X	-	-
Flexibility	-	-	X
Industrial Development	X	-	-
Ease of Implementation	-	-	X
Compatibility With Plans	X	-	-
Cost	-	-	X

There is no simple answer to this question. Following certain development options may preclude all but one choice. When this does not occur, costs must be compared in deciding whether the higher level of service offered by the two guideway systems compensates for their added cost, complexity of implementation, and loss of flexibility.

The principle conclusion of this evaluation must be that none of the three technologies is best, from the non-economic perspective. Therefore, a decision cannot be made simply by weighing service against cost. Figure 8.4 lists the other issues which must be taken into consideration. They are illustrated conceptually in Figure 8.5.

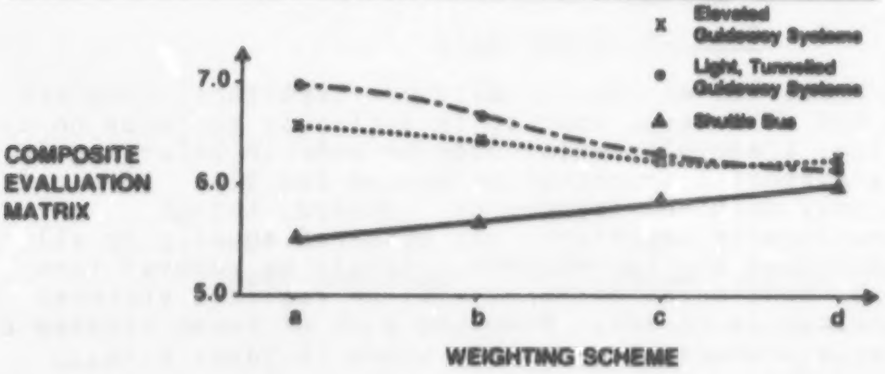

Figure 8.4 Composite Evaluation Matrix

. Level of Service		. Cost
. Support of Airport and Other Development Plans	versus	. Flexibility
. Industrial Development Benefit to Canada		. Ease of Implementation

Figure 8.5 Critical Trade-offs

The important question of cost has not been dealt with up to this point because it depends on demand (i.e., the path chosen through the decision tree). The next chapter demonstrates how the evaluation procedure described above can be applied in practice.

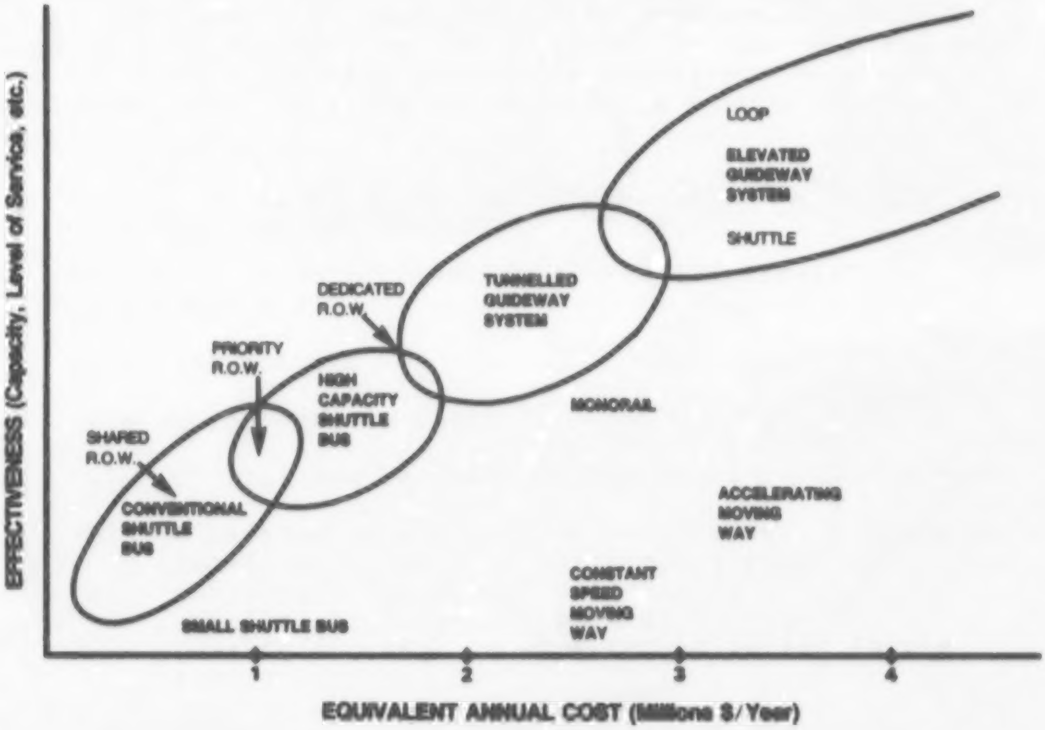

Figure 8.6 Envelope of Optimal Intra-airport Transportation Systems

9. CASE STUDIES

This chapter contains three case studies. They illustrate the ground transportation implications of following three different paths through the decision tree of TIA operating policy and land-use development options. The three paths were selected because they were thought to be of particular interest to TIA planners. They represent a wide range of potential ground transportation demands. Note that these case studies are only intended to illustrate the application of the evaluation procedure explained in this report. The conclusions of the case studies are valid, but apply only to the case study in question. The fact that a particular path through the decision tree has been chosen is not an endorsement of that particular development option. Choosing a development option will require that a great many more factors than merely ground transportation be considered, factors which are beyond the bounds of this study.

9.1 Case Study 1: No Terminal 3, Central Parking Garage (Status Quo)

This airport development option is illustrated in Figures 9.1 and 9.2.

9.1.1 Assumptions

This option assumes that:

(a) T3 will not be built in the short to middle term.

(b) A parking garage will be constructed in the area immediately north of the airport administration building. The garage will handle the present overflow from the car-park at T1, where the parking shortage is expected to worsen in the future.

(c) Employees will not be carried on the intra-airport transportation system. They will continue to have their own service from the north parking lot.

(d) A central (bus) ground transportation terminal will not be constructed.

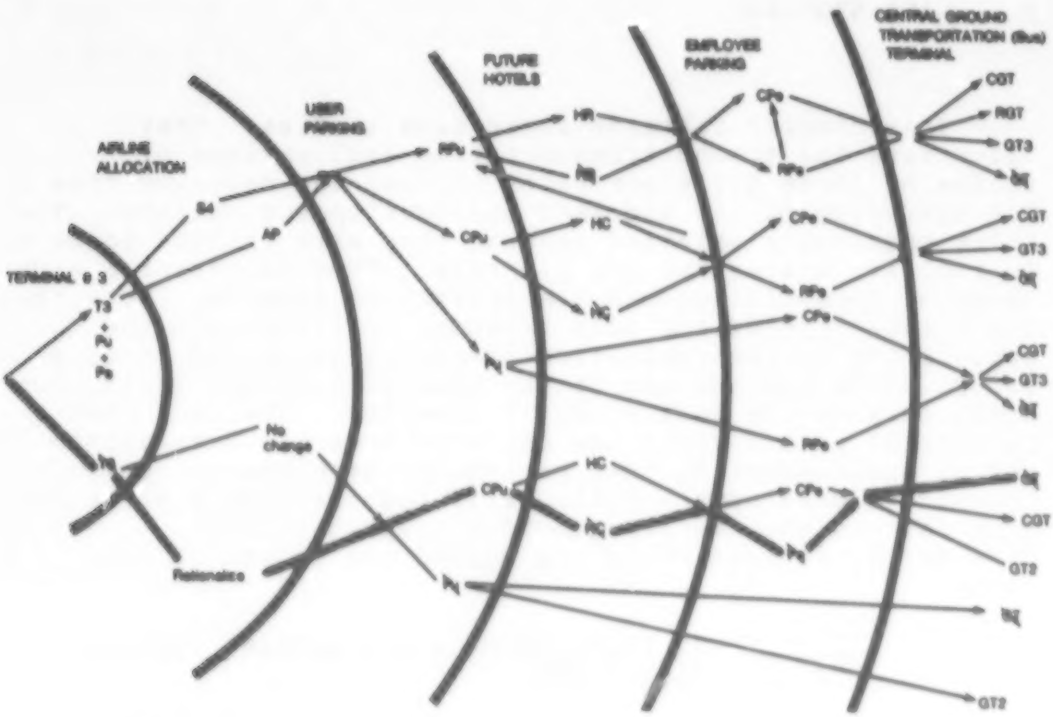
CENTRAL GROUND TRANSPORTATION (Bus) TERMINAL
EMPLOYEE PARKING
FUTURE HOTELS
USER PARKING
AIRLINE ALLOCATION
TERMINAL # 3
T3
Pu
Pe
S4
AP
No change
Rationalize
RPu
CPu
HR
HC
CPe
RPe
CGT
RGT
GT3
GT2

Figure 9.1 Case Study 1: Decision Tree Path

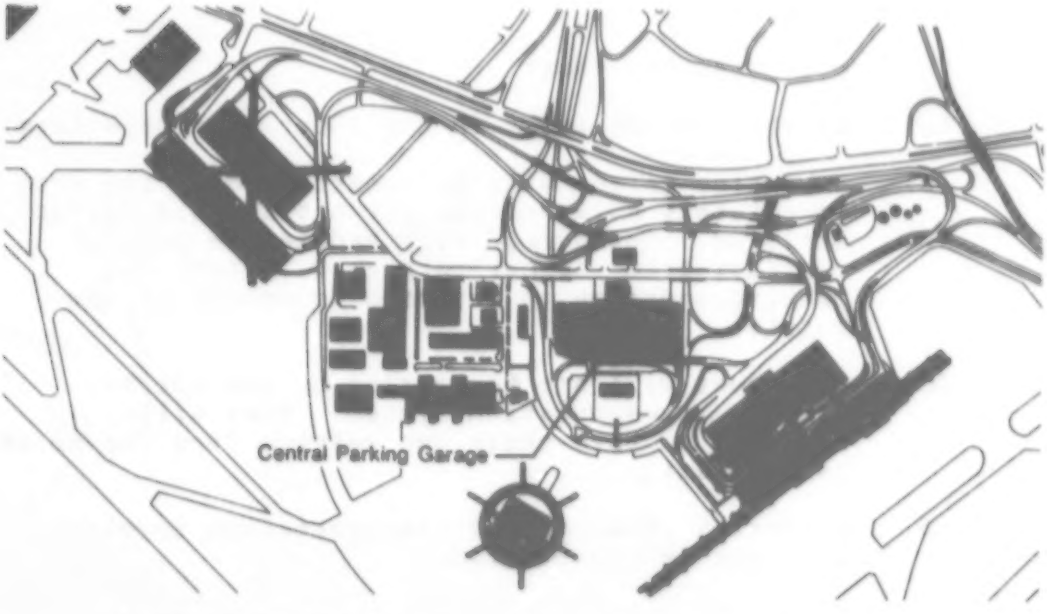
Central Parking Garage

Figure 9.2 Case Study 1: Activity Centre Layout

9.1.2 Choice Constraints

The decision to build a central garage rules out the light tunnelled guideway because this system would not serve the area north of the administration building. Two choices remain: the intermediate capacity elevated guideway and the shuttle bus.

9.1.3 Demand/Capacity Constraints

The decision not to build T3 in the short to middle term implies a fairly pessimistic outlook for further air traffic growth. Therefore, this analysis uses a conservative 1 per cent growth rate. Figure 9.3 shows the expected growth in annual demand on this option over the planning period (dashed line). Peak hour demand on the critical link between the garage and T1 reachs capacity in the first year of service, thus precluding the shuttle-bus option if the capacity limit of 1,500 passengers per hour per direction is accepted for such a system.

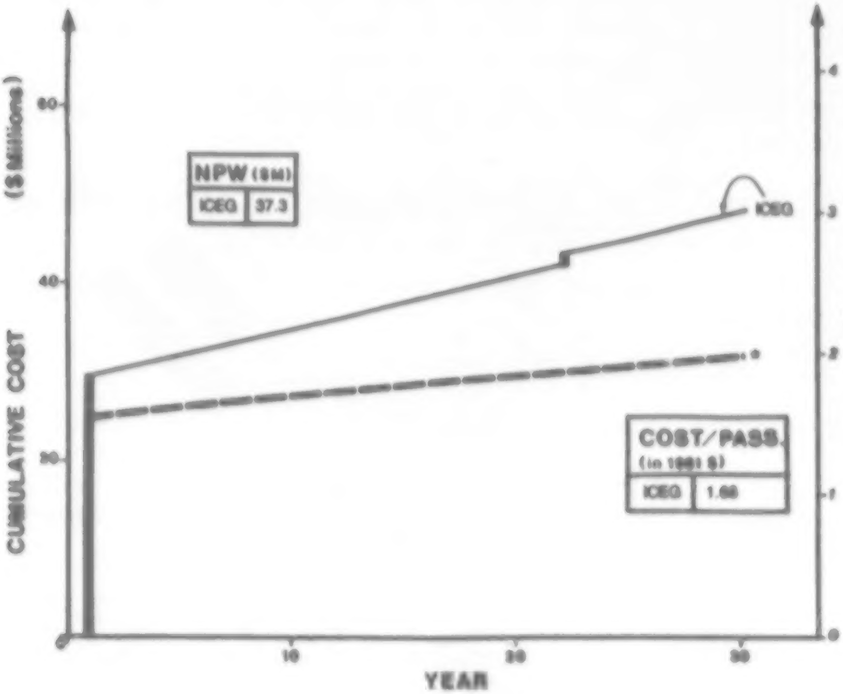

Figure 9.3 Case Study 1: Demand Projection and Financial Analysis

9.1.4 The Choice

With both the shuttle bus and the light tunnelled guideway eliminated, the only alternative is the intermediate capacity elevated guideway. There is, in fact, no choice. Figure 9.3 shows the life-cycle cost (net present worth) of the elevated guideway and the revenue per passenger needed to break even.

This case study illustrates how the combination of a choice constraint and capacity constraint can simplify the decision.

9.1.5 Discussion

The heaviest demand on the intermediate capacity elevated guideway would be between T1 and the central parking garage. Alternative means of serving this single heavy demand flow could be considered. The most obvious of these would be a pedestrian bridge with moving walkways. However, the cost of the conveyor equipment alone would exceed $5.5 million. In addition, the walkway bridge would have to be constructed to the same standards as the elevated guideway, and be heated and air-conditioned. The cost of this option would be equal to or above that of the guideway systems, without either the same high level of service or potential for system expansion to meet the longer-term needs of the airport.

9.2 Case Study 2: Terminal 3, No Central Complex (Minimum Demand)

This airport development option is illustrated in Figures 9.4 and 9.5.

9.2.1 Assumptions

This option assumes that:

(a) T3 will be constructed and air traffic will be diverted to it according to Transport Canada's preferred airline allocation plan.

(b) A parking garage large enough to handle the demands for parking at T3 and any overflow from T1 will be constructed at the same time as T3.

(c) Employees will not be carried on the system. They will be bused from either remote car-parks or a central employee parking garage on a bus system contracted by the airlines.

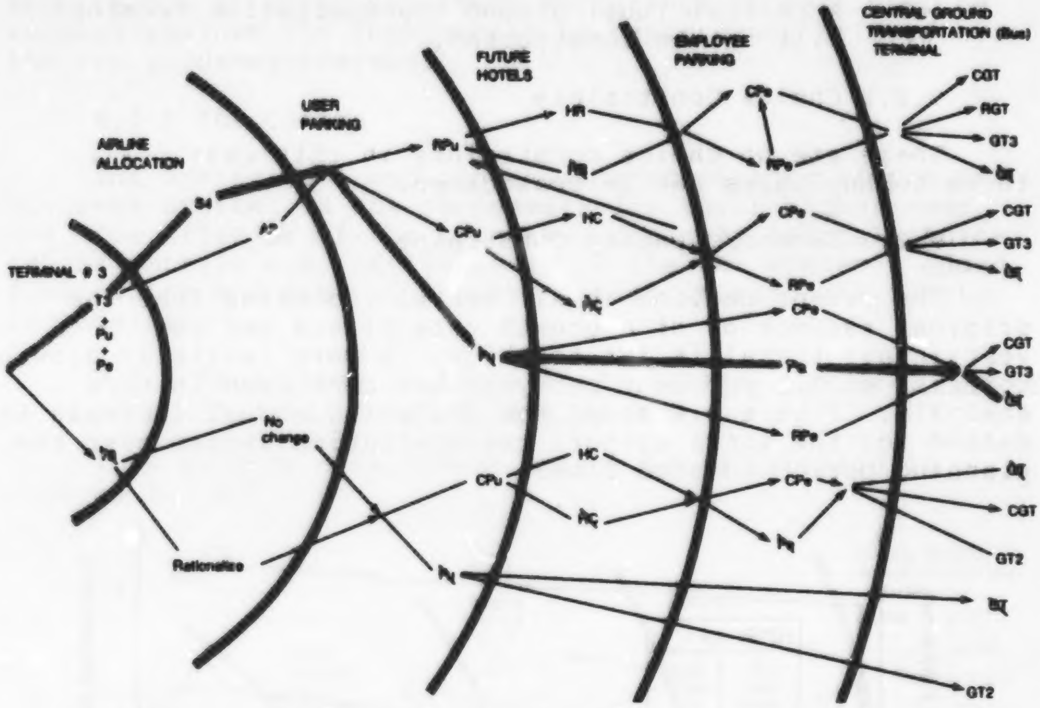
CENTRAL GROUND
TRANSPORTATION (Bus)
TERMINAL
FUTURE
HOTELS
EMPLOYEE
PARKING
USER
PARKING
AIRLINE
ALLOCATION
TERMINAL # 3
T3
+
Pu
+
Pe
S4
AP
No
change
Rationalize
RPu
CPu
CPu
HR
HC
HC
CPe
RPe
CPe
RPe
CPe
RPe
CPe
CGT
RGT
GT3
CGT
GT3
CGT
GT3
CGT
GT2
GT2

Figure 9.4 Case Study 2: Decision Tree Path

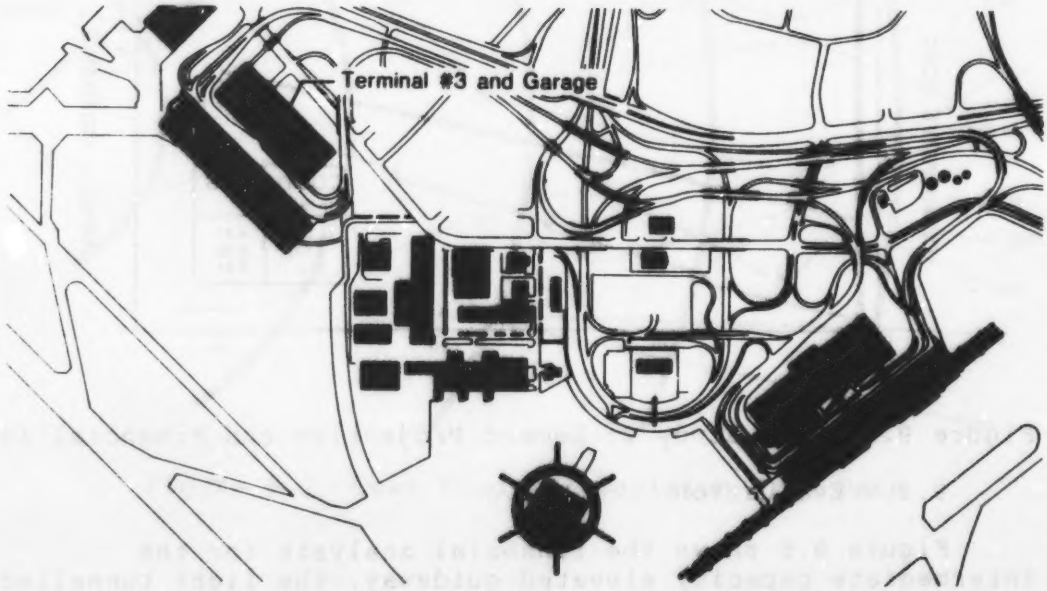
Terminal #3 and Garage

Figure 9.5 Case Study 2: Activity Centre Layout

(d) A central (bus) ground transportation terminal will not be constructed.

9.2.2 Choice Constraints

There are no choice constraints in this case. All three technologies can be considered.

9.2.3 Demand/Capacity Constraints

The recent decline in air travel indicates that the original assumption of a growth rate of 4.6 per cent per year in air travel is far too high. A more realistic growth forecast of 3.1 per cent per year has been used in this analysis. Figure 9.6 shows the projected annual increase in demand for the intra-airport transportation system over the planning period (dashed line).

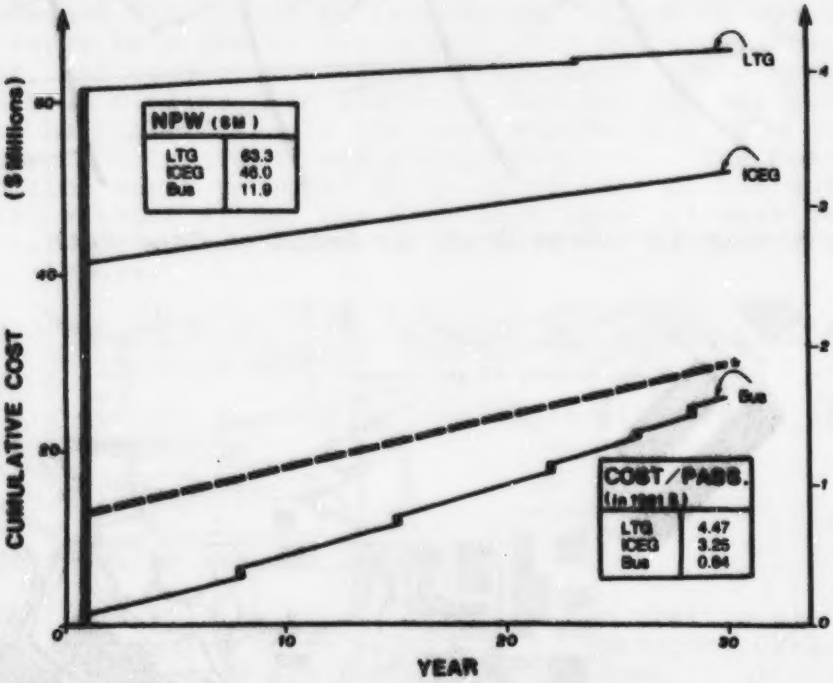

Figure 9.6 Case Study 2: Demand Projection and Financial Analysis

9.2.4 Evaluation

Figure 9.6 shows the financial analysis for the intermediate capacity elevated guideway, the light tunnelled guideway, and the shuttle bus. The net present worth of the two guideway alternatives are several times that of the shuttle bus alternative. This difference in cost must be weighed against the improvement in performance offered by the two guideway systems.

9.2.5 The Choice

The operational and convenience advantages of the two guideway systems do not compensate for their higher cost over the lifetime of the project. The only logical choice is the shuttle bus, particularly if the bus system's added flexibility and ease of implementation is also taken into consideration.

9.3 Case Study 3: Terminal 3 Central Complex, Remote Parking (Maximum Demand)

This airport development option is illustrated in Figures 9.7 and 9.8.

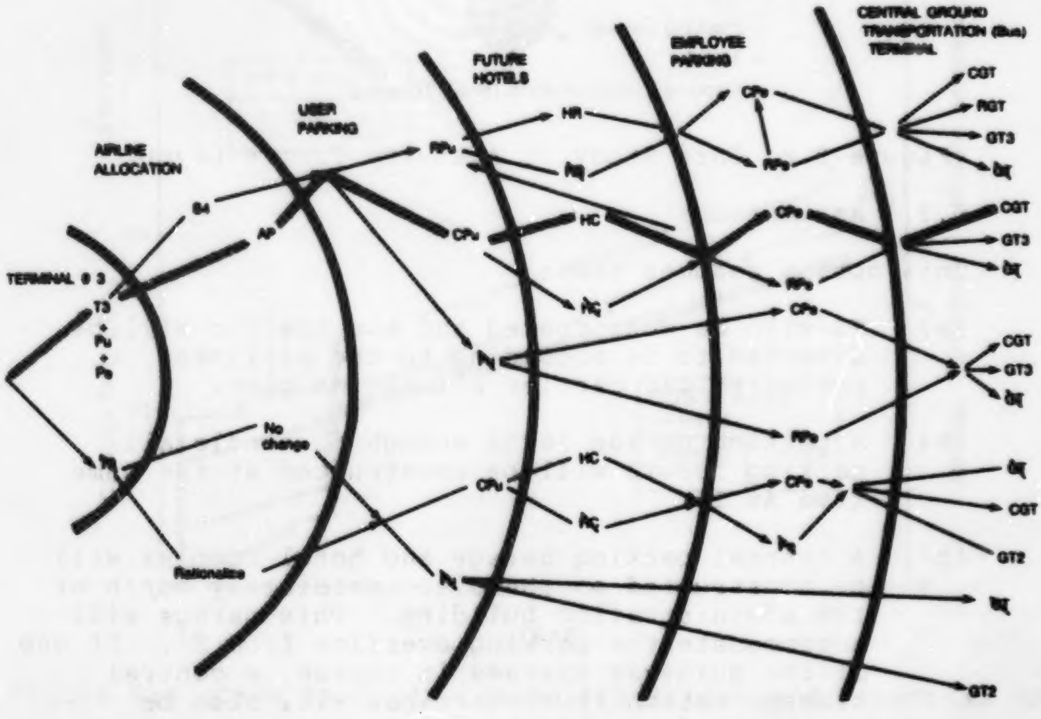
AIRLINE ALLOCATION
USER PARKING
FUTURE HOTELS
EMPLOYEE PARKING
CENTRAL GROUND TRANSPORTATION (Bus) TERMINAL
TERMINAL # 3
T3
+
Pu
+
Pe
B4
AP
No change
Rationalize
RPu
CPu
HR
HC
CPe
RPe
CGT
RGT
GT3
GT2

Figure 9.7 Case Study 3: Decision Tree Path

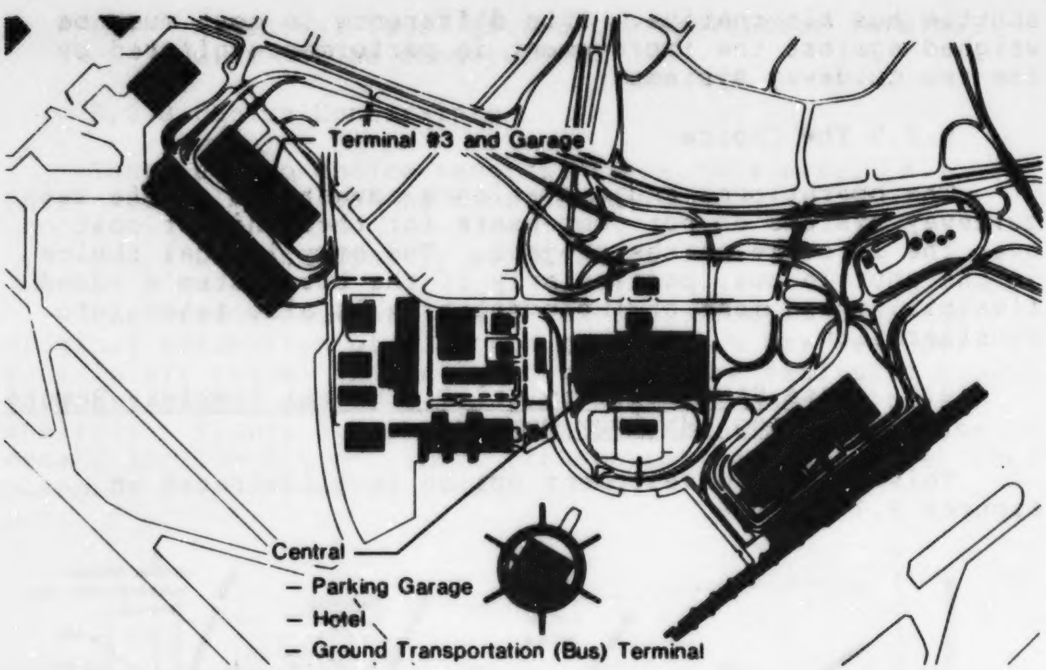
Terminal #3 and Garage
Central
– Parking Garage
– Hotel
– Ground Transportation (Bus) Terminal

Figure 9.8 Case Study 3: Activity Centre Layout

9.3.1 Assumptions

This option assumes that:

(a) T3 will be constructed and air traffic will be diverted to it according to the airlines' preferred air carrier allocation plan.

(b) A parking garage large enough to handle all parking for T3 will be constructed at the same time as T3.

(c) A central parking garage and hotel complex will be constructed on the site immediately north of the administration building. This garage will accommodate the parking overflow from T1. If one of the guideway systems is chosen, a central transportation (bus) terminal will also be constructed at this location.

(d) Employee car-parks will be provided north of Airport Road and employees will be carried to and from this car-park on the intra-airport transportation system.

9.3.2 Choice Constraints

The choice of a central garage rules out the light tunnelled guideway because this system would not serve the area north of the administration building. Two choices remain: the intermediate capacity elevated guideway and the shuttle bus.

9.3.3 Demand/Capacity Constraints

A growth rate of 3.1 per cent per year in air traffic demand is assumed, as it was in Case Study 2. Figure 9.9 shows the forecast growth in air traffic over the planning period (dashed lines). The shuttle bus would only be capable of coping with demand over the first ten years of operation, after which a higher capacity guideway system would be required.

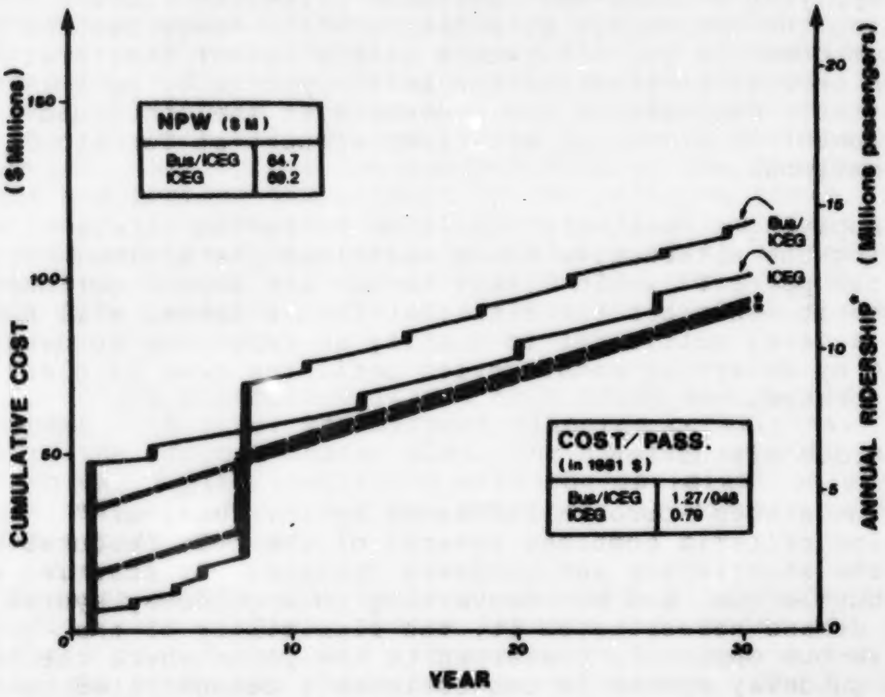

Figure 9.9 Case Study 3: Demand Projection and Financial Analysis

9.3.4 The Choice

There are two possible courses of action:

(a) Opt for the intermediate capacity elevated guideway immediately. This depends on whether its advantages outweigh its added cost. The financial implications of such a choice are presented in Figure 9.9.

(b) Opt for a staged approach, using the shuttle-bus system until it could no longer cope with demand, and then switching to one of the guideway systems. A guideway station would be included in T3. The financial implications of this phased approach are also shown in Figure 9.9.

Applying a "maxi-max" decision criterion (i.e., choosing the technology alternative which maximizes the maximum possible pay-off) would likely favour the first option because it presents the best opportunity to comfortably meet demand and proceed with the continued development of a modern, efficient airport at Toronto International.

Applying a "maxi-min" decision criterion (i.e., choosing the alternative which maximizes the minimum possible pay-off) would likely favour the second option, because it minimizes the risk that future demand will not reach a level sufficient to justify an expensive guideway system by deferring construction until the need is clearly demonstrated.

9.3.5 Discussion

The staged approach indicated by the "maxi-min" decision criteria combines several of the best features of both the shuttle-bus and guideway options. By starting with the shuttle bus, and not converting to a guideway system until demand necessitates it, the flexibility of the shuttle-bus option is preserved to the point where the need for a guideway system is unquestionably demonstrated by actual (not forecast) demands. The decision to convert to the more costly system could then be made with much greater confidence. The long-term costs of this approach are also minimized because the large initial capital required for a guideway system is postponed for as long as possible. The long-term development interests of the airport are served by the fact that provision is made from the outset to convert to a guideway system, if and when it is justified.

10. CONCLUSIONS AND RECOMMENDATIONS

In 1980 the planning staff of Toronto International Airport asked the Transportation Development Centre of Transport Canada to study the intra-airport transportation requirements at the airport to the year 2000, and to develop and assess alternative plans to meet these requirements. The need for this study was precipitated by the planning of a third terminal at the airport, which, once it is completed, will increase the number of inter-airline transfers. The Transportation Development Centre was asked to develop an analytical tool and method to assess the transportation system options for connecting the key airport activity centres.

In addition to serving inter-terminal transfers, an improved intra-airport transportation system would: (1) reduce the problems caused by severe traffic congestion on the airport road system, particularly on the approach to Terminal 1; (2) help to ease the parking shortage at Terminal 1, which will be aggravated by the construction of Terminal 3; (3) improve the productivity of the regional bus systems now serving the airport by centralizing their operations; (4) promote a shift to transit for airport employees and users by providing a high-quality connection between the airport's activity centres and the proposed rail transit link; and (5) serve an airport hotel, should one be built.

To ensure a proper balance, this study was carried out in concert with other key airport planning activities, namely: the airport master plan, the airside capacity plan, the Terminal 3 plan (beginning with the optimization study of Terminals 1 and 2), and the Metropolitan Toronto rapid transit expansion plan.

Because of the wide range of possible alternatives (including technologies, system layouts, and modes of operation) for an improved intra-airport transportation system, the study was conducted in two phases. The first phase examined transportation system alternatives using seven critical criteria: (1) life-cycle cost; (2) convenience to users; (3) accessibility to airport activity centres; (4) reliability; (5) ease of implementation; (6) flexibility to meet unforeseen changes in demand; and (7) environmental impact. This first-phase evaluation provided a shortlist of three technology alternatives, each of which is optimal over a particular range of applications to the airport. These alternatives are:

- Elevated Guideway Systems: For high-demand situations (1,500-5,000 passengers per hour per direction [pphpd]) using large (60-120 passenger) electrically powered trains, e.g. UTDC or Westinghouse operating on an elevated, concrete guideway.
- Tunnelled Guideway Systems: For medium-demand situations (500-2,000 pphpd) using small (36-60 passenger), automated, electrically powered trains, e.g. WEDway operating in a tunnel.
- Shuttle-Bus System: For low-demand situations (0-1,500 pphpd), using conventional (35-50 passenger) diesel transit buses operating on priority or dedicated rights-of-way.

Demand estimates were prepared from nominal schedules for the years 1985, 1991, and 2000. From these, peak-hour and annual ridership estimates were formulated for each potential land-use development and/or policy option. Phase two of the study set out to determine which of the candidate transportation systems identified in phase one would best serve each of the operating policy and land-use development options and, in so doing, to trace out the intra-airport transportation implications (i.e., required capacity, level of service, cost, etc.) of each of these options.

A greatly expanded list of criteria was considered in the second phase of the analysis, including: comfort, safety and security, luggage and cargo handling capability, equity, and energy consumption. Functional designs were produced for each of the technology alternatives, defining routes, station locations and layouts, operating schedules, etc.

A computer model was developed to assist in the evaluation. By specifying the anticipated annual growth rate for air traffic, the desired land-use development plan, the transportation system, the discount and inflation rates, the expected useful life of equipment, maximum capacities, minimum policy headways, and hours of peak and off-peak operation, the project team determined the life-cycle costs and level-of-service parameters for the three technology alternatives.

This study provides a tool to help decision-makers evaluate development options. Because there are so many options, it was not practical to evaluate them all. Instead, three options of particular interest to the airport planning staff were analyzed as case studies.

Case Study 1

This assumed an annual passenger growth rate of 1 per cent and therefore does not provide for a third passenger terminal in the short or medium term.

This also assumed that a central parking garage will be built north of the administration building to accommodate existing and future shortages at Terminal 1. No provision is made for employees to use the transportation system, nor for a centralized ground (bus) transportation terminal.

Case Study 2

This assumed an average annual growth rate of 3.1 per cent and that a third terminal (with parking garage) will be built. As with Case Study 1, no provision is made for employees to use the transportation system, nor for a centralized ground transportation terminal.

Case Study 3

This assumes the same annual traffic growth rates and passenger terminal configuration as in Case Study 2. In addition, it assumes that a central ground transportation terminal and a parking and hotel complex will be built north of the administration building. Provision is also made to accommodate airport employees on the system.

Four conclusions were drawn from this study:

1. This study provides decision-makers with a clear understanding of the ground transportation implications of pursuing any one of a wide range of development options for Toronto International Airport. It assists decision-makers in selecting an appropriate transportation system for a specific development option. Information about the impact of non-user, (e.g., traffic congestion) on the development options is not currently available, but it must be accounted for in the decision process.

2. If a third terminal is not built in the short to middle term (Case Study 1), and every effort is made to optimize the use of the existing facilities, then the capital investment in an elevated guideway system is both required and justified. A guideway system would ensure that the available groundside capacity at Terminal 2 can be mobilized in support of Terminal 1. It would also ensure that adequate capacity and level of service can be provided on the

critical link between Terminal 1 and the central parking garage required to accommodate the parking overflow at Terminal 1.

3. If a large capital investment is made in a self-contained third terminal (Case Study 2) designed to relieve the congestion at Terminal 1, then there is little or no justification for large investment in an intra-airport transportation system because inter-terminal transfers will be minimal.

4. A high-performance intra-airport transportation system will be required if a third terminal is built and (1) the airlines' preferred scenario for carrier allocation to the terminals is adopted; (2) the transportation system is to carry employees; and (3) a central (bus) ground transportation terminal is built. In other words, with three terminals, the investment in a guideway system can be justified if certain policy decisions are made about employee use, access, etc. (Case Study 3).

The conclusions of this study must not be considered in isolation. Rather, they must be assessed in conjunction with the traffic engineering analysis, the airside capacity analysis, and the terminal needs analysis, in order to evaluate the full range of options open to the airport. A balanced approach must be sought under which all opportunities and constraints are considered and an optimal staged approach to the future development of Toronto International Airport is pursued.

APPENDIX A: List of Working Papers and Reports

TP #	TITLE	DATE
3129E	Interim Report Number 1: Strategic Options and Evaluation Methods	August 1980
2985	Technical Working Paper Number 3: Airport Access Plan Review	March 1981
3046E	Technical Working Papers Numbers 4 and 8: Demand Analysis	October 1981
3047	Technical Working Paper Number 5: Circulation System Alternative	May 1981
3048E	Technical Working Paper Number 6: Literature Review and Site Visit Reports	April 1981
3049	Technical Working Paper Number 7: Preliminary Evaluation of Technical Alternatives	July 1981
2982	Interim Report Number 2: Access Plan Review and Technology Evaluation	October 1981
2939	Technical Working Paper Number 9: Parking Options Analysis	March 1981
3621E	Interim Report Number 3: Parking and Ground Transportation Options	March 1982
3162	Technical Working Paper Number 11a: Shuttle Bus System Layout and Design	September 1981
3226E	Technical Working Paper Number 11b: ICTS Layout and Design	August 1982
3227E	Technical Working Paper Number 11c: WEDway Layout and Design, Volumes 1 and 2.	November 1981

3228	Technical Working Paper Number 11d: Westinghouse People Mover Layout and Design	October 1981
3907E	Technical Working Paper Number 12: Impact Group Evaluation Criteria	September 1982
3696E	Technical Working Paper Number 13a: Facilities Impact and Architectural Requirements - WEDway and Shuttle Bus	July 1982
3695	Technical Working Paper Number 13b: Facilities Impact and Architectural Requirements - ICTS	September 1982
3906E	Technical Working Paper Number 14: Technology Evaluation	October 1982
3890E	TIA Intra-Airport Transportation Study: Final Report	October 1983
3905E	TIA Intra-Airport Transportation Study: Summary Report	October 1983

Note: Technical Working Paper Number 10: Traffic Engineering was deleted from this study.

APPENDIX B: Organization of the Project Team

The project team comprised staff from the Transportation Development Centre, the Toronto International Airport Planning Branch, the Ontario Region Planning and Programming Branch of the Canadian Air Transportation Administration, and the Airport Operations and Maintenance Services Headquarters of the Canadian Air Transportation Administration. Figure B.1 shows their reporting relationship. Figure B.2 shows how their responsibilities were allocated.

Transportation Development Centre was the prime performer. It assigned an engineer, an economist, a transportation planner, and a systems analyst to conduct the bulk of the work required in this study. Transportation Development Centre also sub-contracted specific work packages to consultants.

The Toronto International Airport Planning Branch, the Ontario Region Planning and Programming Branch, and the Airport Operations and Maintenance Services Branch generated the demand data and delivered the ground transportation traffic data based on the revised Groundside Travel Demand Model.

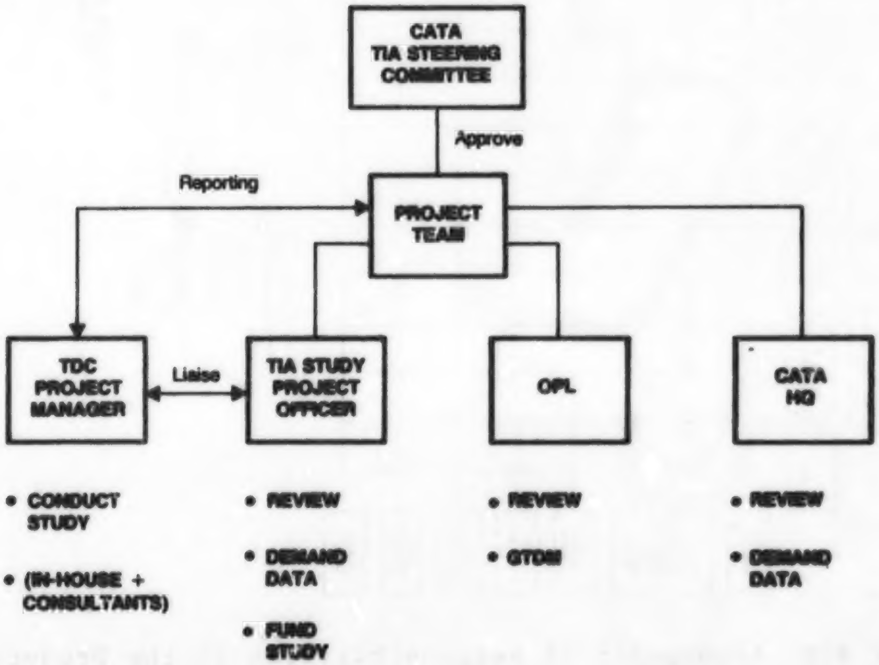
CATA
TIA STEERING
COMMITTEE
Approve
Reporting
PROJECT
TEAM
TDC
PROJECT
MANAGER
Liaise
TIA STUDY
PROJECT
OFFICER
OPL
CATA
HQ
• CONDUCT STUDY
• (IN-HOUSE + CONSULTANTS)
• REVIEW
• DEMAND DATA
• FUND STUDY
• REVIEW
• GTDM
• REVIEW
• DEMAND DATA

Figure B.1 Reporting Relationships

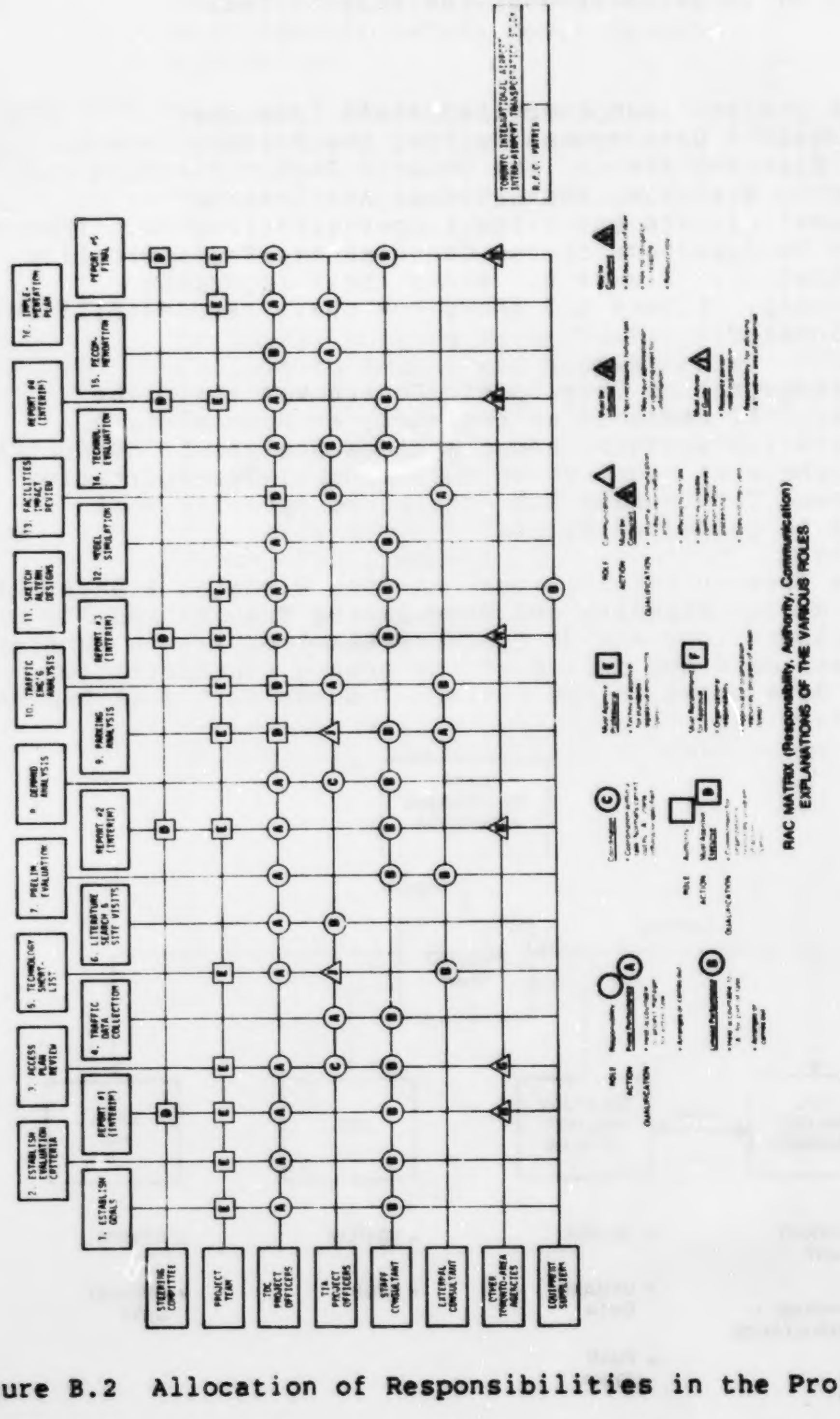
TORONTO INTERNATIONAL AIRPORT INTRA-AIRPORT TRANSPORTATION STUDY
R.A.C. MATRIX
1. ESTABLISH GOALS
2. ESTABLISH EVALUATION CRITERIA
REPORT #1 (INTERIM)
3. ACCESS PLAN REVIEW
4. TRAFFIC DATA COLLECTION
5. TECHNOLOGY SHORT-LIST
6. LITERATURE SEARCH & SITE VISITS
7. PRELIM. EVALUATION
REPORT #2 (INTERIM)
8. DEMAND ANALYSIS
9. PARKING ANALYSIS
10. TRAFFIC ENG'G ANALYSIS
REPORT #3 (INTERIM)
11. SKETCH ALTERN. DESIGNS
12. MODEL SIMULATION
13. FACILITIES IMPACT REVIEW
14. TECHNOL. EVALUATION
REPORT #4 (INTERIM)
15. RECOMMENDATION
16. IMPLEMENTATION PLAN
REPORT #5 FINAL
STEERING COMMITTEE
PROJECT TEAM
TIC PROJECT OFFICERS
TIA PROJECT OFFICERS
STAFF CONSULTANT
EXTERNAL CONSULTANT
OTHER TORONTO-AREA AGENCIES
EQUIPMENT SUPPLIERS
RAC MATRIX (Responsibility, Authority, Communication)
EXPLANATIONS OF THE VARIOUS ROLES

Figure B.2 Allocation of Responsibilities in the Project Team